INSIDE! Pull-out star charts

How astronomers glimpse the **NAKED GALAXY** p. 58

February 2007

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What if string theory is wrong?

If it is, then dark matter, dark energy, and cosmic inflation are in big trouble

What makes a monster star tick p. 42

5 simple steps to save our night sky p. 72

AND MORE!

Explore winter's best star clusters p. 68

HOT NEW IMAGES from the Mars orbiter p. 36

Get the most from CCD images p. 78

String theory implies new dimensions of space and a deep symmetry in the quantum realm. p. 30

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The DSI II turned my expensive cooled camera into my primary auto-guider.

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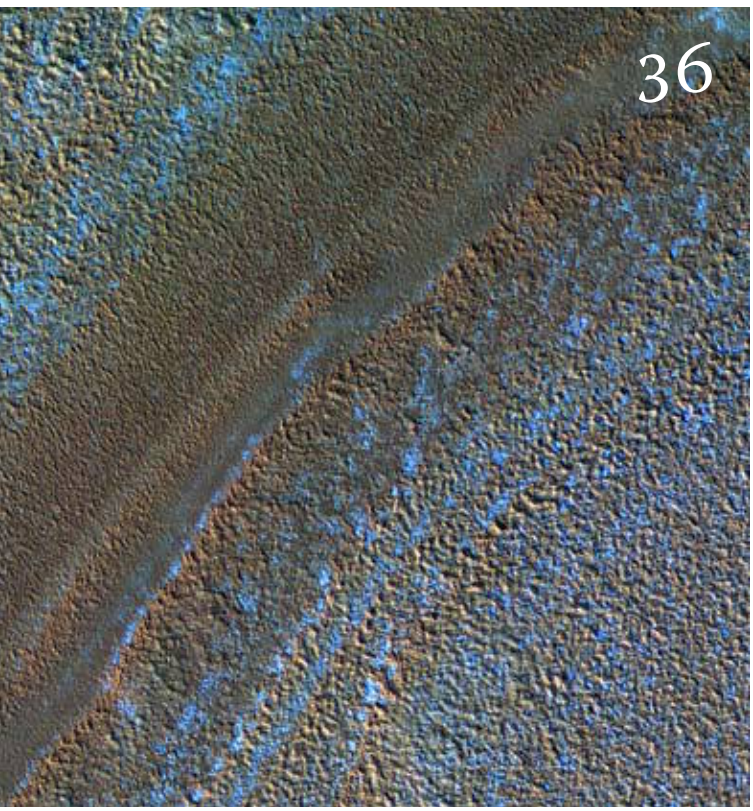

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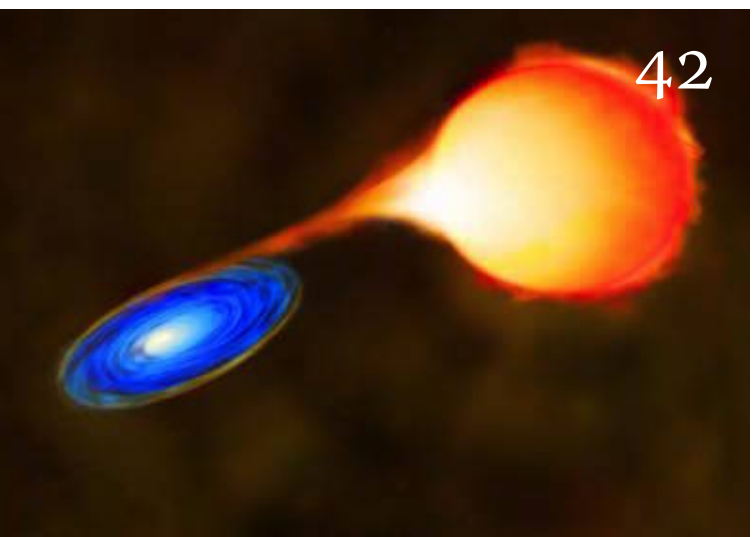

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Astronomy

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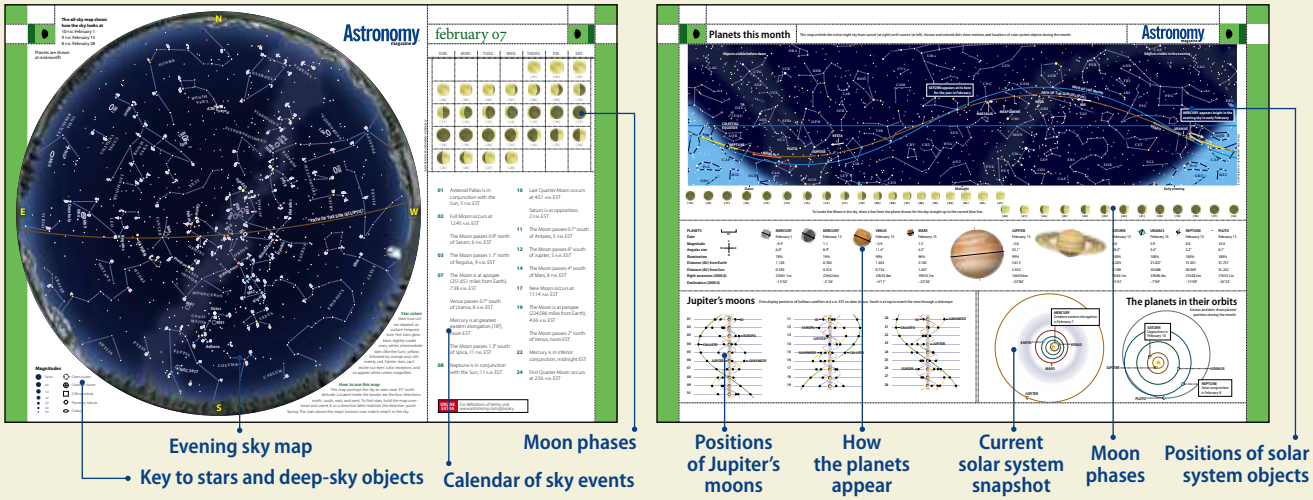

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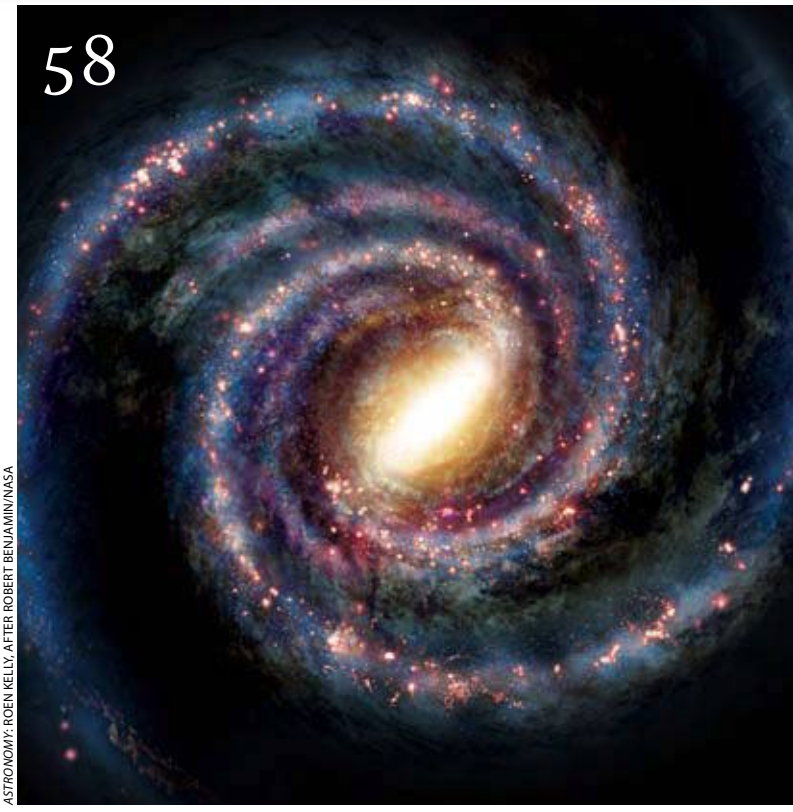

ASTRONOMY: ROEN KELLY, AFTER ROBERT BENJAMIN/NASA

JOHN CHUMACK

BY DAVID J. EICHER

NASA gets it right

NASA made the right decision to send a fifth servicing mission in 2008 to fix the ailing Hubble Space Telescope (HST). NASA Administrator Michael Griffin's October 31 announcement reversed the blunder made by former NASA Administrator Sean O'Keefe, who felt following the 2003 Columbia disaster, another Hubble repair mission would be too risky.

Clearly, NASA engineers need to be as competent and careful as any analytical minds on Earth. They require confidence in the craft they've designed and in the astronauts' safety. The days of employing under-insulated wires in oxygen-rich environments (which caused the Apollo 1 launch-pad fire) and using tiles and insulation that can't withstand the extremes of launch and reentry must remain in the past. But NASA can't turn away from potential risks, either. By definition, spaceflight involves risk — much more than driving to the grocery or flying in a jet.

Risk must be weighed against scientific gain. That's the business NASA is in. And Hubble has returned more top-line science than any other single instrument in history. Thanks largely to HST, astronomers are closer to understanding some of science's biggest mysteries, such as the universe's origins and the formation of the first stars.

Skeptics argue the money could be better spent "down here on Earth." However, scientific spending in the United States is a drop in the bucket compared with other governmental expenditures, such as current foreign-policy costs. If you don't care to know how the universe works, then spending money on Hubble won't make sense to you. But trying to understand our universe is what separates us intellectually from our pets. And this nation had better develop a new generation of expert scientists, or progress with science and technology — and the resulting economic prosperity — will diffuse to other societies that value science more than ours.

The space shuttle Discovery crew will reinvigorate Hubble and extend its lifetime by installing two new instruments: the Cosmic Origins Spectrograph (COS) and the Wide Field Camera 3 (WFC3).

The COS will probe large-scale galaxy superclusters and intergalactic gas, looking for clues to the universe's early history.

The WFC3, an upgraded camera, will enable scientists to capture the best images yet of deep-space objects.

The astronauts also will fix Hubble's fine guidance sensors, the equipment that aims HST, and the Space Telescope Imaging Spectrograph, an instrument that allows high-resolution analysis of distant stars, planetary atmospheres, and galaxies.

Griffin's decision reestablishes NASA's credibility toward doing what is right for science in the United States. Now, if more Americans could embrace science for their futures — and those of their children — this country might be heading somewhere.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 35, Number 2

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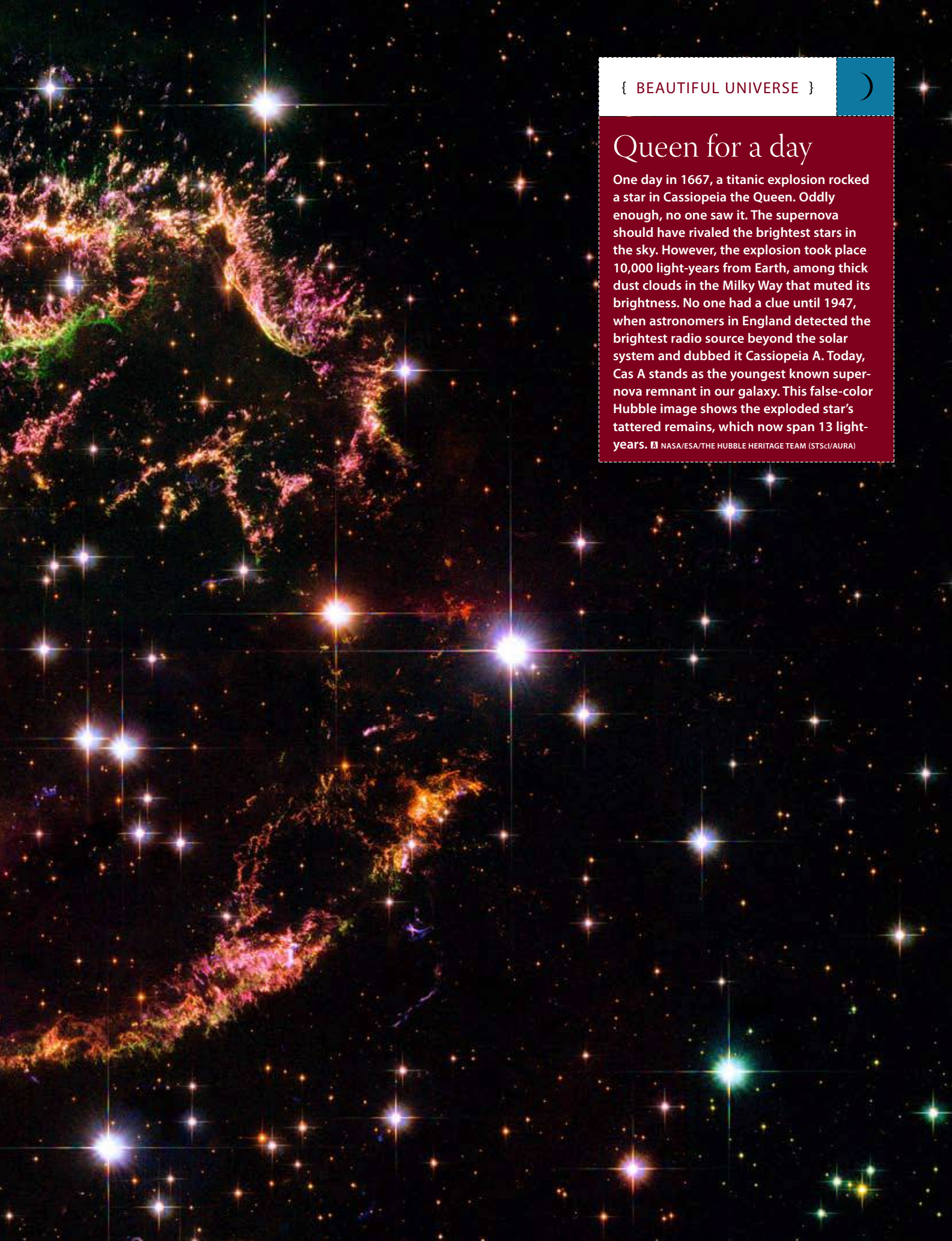

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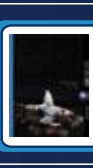

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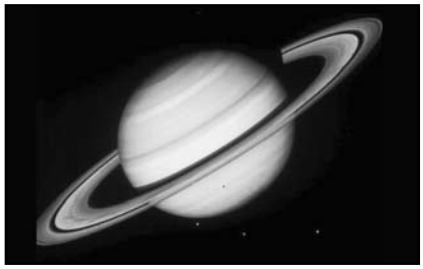
A natural teacher with a Ph.D. in astrophysics from Columbia University, Dr. Neil deGrasse Tyson has written prolifically for the public, including the series of essays in *Natural History* magazine on which this course is based. And though it was created for a lay audience and is readily accessible, the course is one in which science always takes precedence over drama.

It is certainly entertaining, often funny, even awe-inspiring at times, as befits the subject matter. But clear introductions to essential principles of physics abound throughout these lectures, including density, quantum theory, gravity, and even the General Theory of Relativity. And Dr. Tyson also includes forays into disciplines such as chemistry and biology as needed to explain events.

For example, Dr. Tyson begins one lecture at a point 13 billion years ago, when all space, matter, and energy in the known universe were contained in a volume less than one-trillionth the size of a pinpoint—about the size of an atom. By the time he finishes, the cosmos has been stretched, the planets and Earth formed, and 70 percent of Earth species wiped out by a gigantic asteroid—clearing the way for the evolution of humanity.



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Saturn

As Dr. Tyson notes, we are made of stardust, just as the planets are. And he has created a course that explains exactly how that came to be, beginning with a grounding in the basic "machinery" of matter, forces, and energy which reveals itself throughout the universe.

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Beyond the solar system

Your October issue on extrasolar planets was outstanding! But I must disagree about the top 10 places to look for life in Margaret Turnbull's "Where is life hiding?" The most likely star system for life is a G- or K-type star where we have not yet found any companions. Today, astronomers would not be capable of detecting any of the planets in our solar system if Sol were 30 light-years away.

Because we now suspect most stars have planets, let's look at those star systems that most reflect how our solar system developed. The five candidates for the Terrestrial Planet Finder are better choices. — **ROBERT POWELL,** AUSTIN, TEXAS

The extrasolar planets special issue was fantastic, with informative, excellent, well-written summaries by Geoff Marcy, Alan Boss, María Rosa Zapatero Orsorio, Richard Talcott, and Margaret Turnbull. The pullout poster by Talcott and Lynette Cook was especially spectacular — a real "keeper."

As a serious astrophysics amateur, I was impressed with how everyone brought the exoplanet material together and presented it in such an enlightening manner. Wow! — **JOHN MacKELLAR,** GREENHILLS, OHIO

NASA/ESA/G. BACON (STScI)

EXOPLANETS took center stage in the October 2006 *Astronomy*. This artist's concept shows a gas-giant planet orbiting a red dwarf.

Spirit of adventure

Bob Berman may be correct when he says, "Space travel might be a dangerous bummer" ("Space-travel woes," October 2006). Such circumstances may well hold true, just as they did for those who crossed America in covered wagons.

The woes concerning space travel will remain paramount until engineers stop thinking about manned spacecraft in terms of how many instruments can be crammed into them, and more in terms of how to make them comfortable for their crews and passengers. — **MICHAEL WOLFF,** NORTH CHARLESTON, SOUTH CAROLINA

I am glad Berman's attitude was not around when humans started to sail the oceans in exploration of our planet. There were plenty of dangers associated with those travels, including mental isolation and physical-health issues. Perhaps they should have all just stayed at home, too?

One of humankind's greatest abilities is being able to adapt and grow. We will only be limiting ourselves if we remain on Earth, just as the early voyagers would have done if they had just decided to stay where they were. — **BART PRITZL,** ST. PAUL, MINNESOTA

Corrections

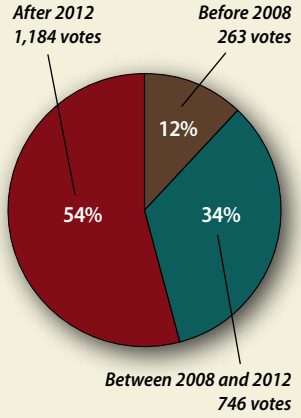
In the image on page 96 of the October 2006 issue, the bright dot to the Moon's upper right was mistakenly identified as Mercury. It is actually the star Delta (δ) Piscium. Mercury lies to the Moon's lower right, below the horizon.

Mercury passes between the Sun and Earth 3 or 4 times a year, not 4 or 5 times, as stated in "Mercury crosses the Sun" (November 2006). The difference takes into account Earth's orbital motion, not just Mercury's. — ***ASTRONOMY* EDITORS**

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

Online poll results

POLL QUESTION:
When will astronomers find an earthlike exoplanet?



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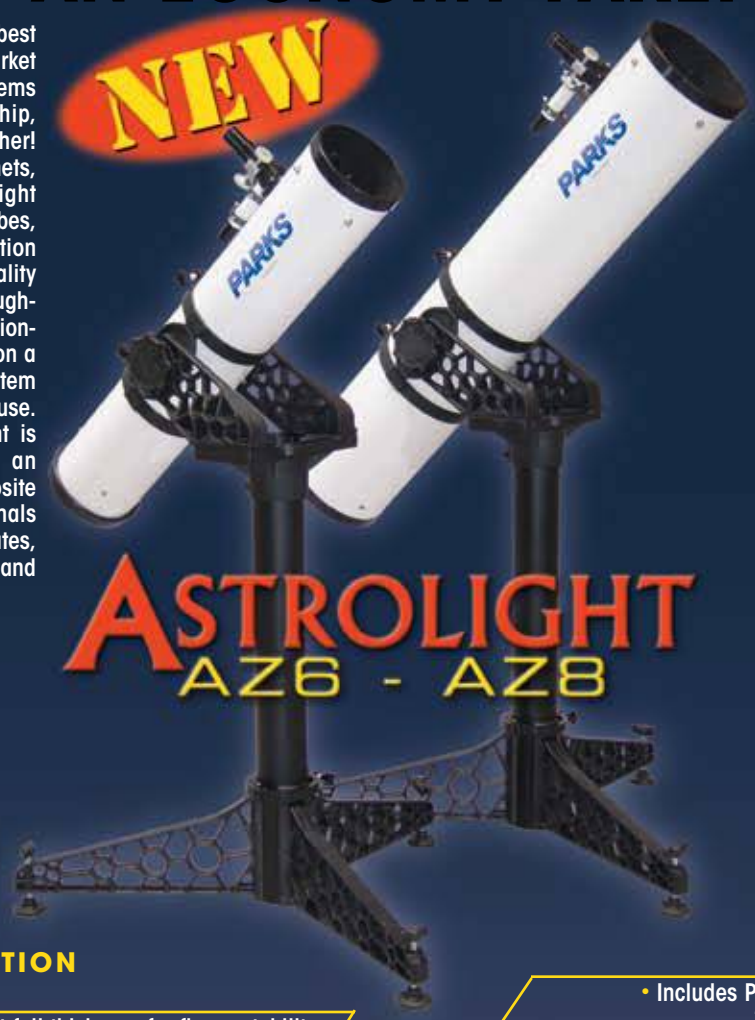

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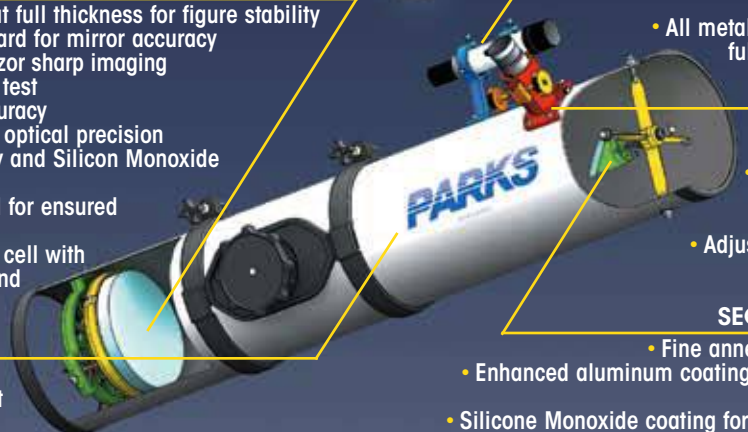

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BY BOB BERMAN

Missing shadows

Shadows. Ordinary shadows. Amazingly enough, they help solve cosmic mysteries — but now they're torturing us with a new one. We're exploring this now, of course, because this month the topic of shadows gets its yearly makeover. It's time for our most bizarre annual

ritual, when a rodent with a 4-ounce brain makes meteorological predictions.

Punxsutawney Phil emerges February 2 and looks around apprehensively. He ignores the intimidating crowd of cold, loud humans, and, instead, obsesses on his own shadow. This alone so spooks him that every low-pressure weather system for the next 6 weeks dumps snow on the continent. No, Groundhog Day does not exactly mark the high point of human logic.

But shadows do have a serious, legitimate place in astronomy. By blocking the Sun in May 1918, the Moon's shadow proved that space bends and Einstein was right. The shadows of Jupiter's moons help astronomers establish those satellites' orbital parameters. Earth's million-mile-long shadow so varies its color that when it hits the Moon during an eclipse, it delivers a report on our global air quality, as observers in eastern North and South America will witness a few weeks from now, on March 3. Now shadows are in the news again, to help clarify the universe's origin. Except, these shadows are not cast by visible light.

There are all sorts of unseen shadows out there; most of us have dealt with some of them. If you've ever sat around a fire on a cold night, you faced the flames to keep your skin nice and toasty. If big people stepped between you and the fire, you felt instantly cold because they blocked the fire's infrared photons. Put another way, those people were casting infrared shadows.

Shadows can reveal surprising information. If you dangle an eraser attached to a thread above white cardboard on a sunny day, you'll see the eraser's shadow, duh. Hold the cardboard perpendicular to the Sun so the shadow isn't distorted. Slowly move the eraser away, and the shadow no longer matches the shape of the eraser. Instead it's perfectly round. You are blocking out exactly one image of the Sun. In essence, you're projecting a negative picture of the Sun onto the cardboard.

It turns out every sunlit surface is made up of countless solar images that overlap. With your suspended eraser, you blocked out one of them. So what did the shadow show? The eraser — or the Sun? Bottom line: All by itself, a shadow can reveal hidden information about the light source.

> ALL BY ITSELF, a shadow can reveal hidden information about the light source.

Rewind to the Big Bang when, in a flash, unimaginable energy permeated all of space and created protons and electrons. There were — and still are — a billion photons for every particle in the universe, but these photons, despite their overwhelming numbers, couldn't penetrate through the glowing fog of ionized particles.

Then, 350,000 years after the Big Bang, the universe expanded and cooled enough for normal hydrogen atoms to form. The ionization ended, and the universe became transparent. Light stopped bouncing around off things and now headed in straight paths through the cosmos.

That brief period, when ionization ended everywhere and light scattered for the final time, still can be observed far off in the distance. It's a wall of light that originated way back when the cosmos was a glowing fog, with an age of just 350,000 years. This energy comes from all directions equally. It emanates from where the ionized universe was located just before it became transparent.

As space expanded, light waves stretched like saltwater taffy. Today, they consist of lazy microwaves that are as omnipresent as Alaskan mosquitoes. Because it all emanates from the same precise time, and therefore the same distance from us, large foreground objects ought to block out these microwaves — in effect, producing microwave shadows.

But this past September, astronomers published analyses of data from the sophisticated Wilkinson Microwave Anisotropy Probe observatory, and found that many galaxy clusters cast no shadows at all. No shadows? How could this be?

The most logical answer is that the cosmic microwave background (CMB) originates from space that's nearer than the galaxies. In that case, the CMB does not come from any wall of light at the edge of the visible universe — and we have to throw out the Big Bang. Or maybe those galaxies give off their own microwaves, thus "filling in" their shadow. But why would so many galaxies emit microwaves of exactly the same precise 2.725-Kelvin temperature? It makes no sense. Or maybe something's wacky with the data.

We need a shadow expert. We could call Punxsutawney Phil, but the little groundhog isn't talking.

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BY GLENN CHAPLE

Watching the sky move

It's true, I have no life. I'll stare at a clock for minutes on end, to see if I can pick up the minute-hand motion. I can detect this subtle movement by using the little minute markers as reference points. Try it, if you have plenty of time on your hands. Translation: You have no life.

I'm fascinated by barely perceptible slow-motion phenomena and found the following e-mail from Bill Cromwell of Fort Louden, Pennsylvania, especially interesting: "Do observers ever notice Earth's rotation with just the naked eye? I have found, on more than one occasion that I can get into 'the zone' as they say, and for brief moments, 'see' the sky shift. By using a soft focus and peripheral vision, I've been blown away by this very intense experience. So I was wondering if you have ever heard of this … or perhaps I've just lost my mind!" In a follow-up e-mail, Bill adds that the momentary effect is especially noticeable when he's gazing at the southern sky.

No, Bill, you're not losing your mind. Have you spent hours staring at clocks? I'm intrigued by Bill's observation and wonder if other readers have had similar experiences. If you've detected the sky's diurnal motion, e-mail me at gchaple@hotmail.com.

While I've never sensed the kind of diurnal drift of stars the way Bill has, I have observed this motion with the help of reference points that serve like a clock's minute markers. One February evening a few years ago, I decided to take a break from variable-star observing. Low in the south, peeking through the tree branches, was Sirius. Sitting perfectly still, I could see the brilliant star wink on and off through the branches as it drifted westward. When Sirius drew near to an isolated branch, I closed one eye to eliminate any parallax effect and waited. Slowly, Sirius "neared" the branch, and then blinked out of sight. Moments later, it reappeared on the other side.

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The effects of Earth's rotation on sky motion are dramatic when a telescope and high-power eyepiece are used. A sky object located near the celestial equator seems to zip across the eyepiece field! I love this effect when I'm viewing the Moon. As I peer into the eyepiece, I get the feeling I'm in a spacecraft orbiting above the lunar surface. Some telescopes come equipped with motor drives that counteract the effects of rotation and keep the target object centered in the eyepiece field. When the Moon is my telescopic target, I prefer the free fall!

Another sky motion results from Earth's revolution around the Sun. Far subtler than diurnal motion, it manifests itself in an east-to-west shift of the stars and constellations. Our friend Orion the Hunter will demonstrate. On a mid-February evening at 7 P.M. local time, the Hunter rides high in the sky. A month later at that same time, Orion appears much farther west. If you go outside at 7 P.M. on a mid-April evening, you'll be hard-pressed to see Orion in the sunset glow above the western horizon.

A third sky motion produced by earthly movement would be all-but-impossible for the casual backyard astronomer to detect. Called precession, it's caused by a periodic wobble of Earth's axis. One wobble takes some 257 centuries, so don't plan on observing its effects on the night sky unless you have been cryogenically frozen, then revived 12,000 years from now. Then, you'll find Polaris is no longer the north-pole star — this honor goes to Vega.

The sky coordinates right ascension and declination are based on the celestial north pole's location and the vernal equinox's position — the time of year around March 21 when the Sun crosses the celestial equator heading north. These points shift because of precession, so star atlases have to be updated periodically. During my early years in amateur astronomy, star atlases were based on the locations of celestial north and the vernal equinox in the year 1950. By 1980, star atlases were being created for "Epoch 2000.0." In a few decades, we'll be purchasing "*Sky Atlas 2050.0*." Let's see, in 2050, I'll be 43 years older. I'm 60 now, so 60, plus 43 would make me … most likely dead! I'd better stop staring at that wall clock and get a life!

A year ago, I introduced you to the beautiful, but under-observed, double star h3945. Amateur Chris Kelly of Troy, Tennessee, saw this pair's colors, which he described as "golden-white" and "bluish." If you didn't heed my advice to put h3945 on your observing list, do so this month, while its parent constellation Canis Major is well-placed in the evening sky.

Questions, comments, or suggestions? E-mail me at gchaple@hotmail.com.

Next month: Encouragement for those of you who, like me, have no life — plus, we run the Messier 5K. Clear skies!

This Year's Nobel Prize for Physics

goes to two men who convinced the scientific world that our universe had a tiny, dense beginning— *Show Me God* tells the story.

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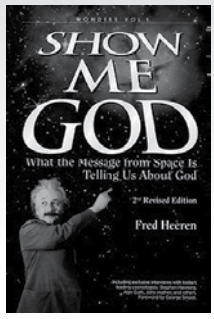

Drawing from interviews with them, as well as with Stephen Hawking, NASA leaders, and other Nobelists, ***Show Me God*** explores how their discoveries affect life's big questions: How did the universe begin? Are there extraterrestrials? Is there evidence for cosmic purpose?

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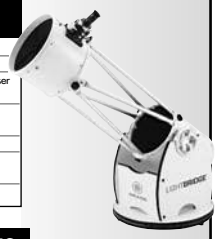

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93301	1¼" – 25mm	$34.00
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93303	1¼" – 6mm	$34.00
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93319	1¼" – 12mm	$44.00
93320	1¼" – 15mm	$44.00
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93322	1¼" – 25mm	$44.00
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94121	Minus V Refractor Filter 1¼"	$49.00
94123	UHC/LPR Filter 1¼"	$69.00
94124	UHC/LPR Filter 2"	$99.00
94125	UV/IR Cutoff Filter 1¼"	$59.00
94119-A	Moon Filter 1¼"	$14.00

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BY PHIL HARRINGTON

The hunter becomes the hunted

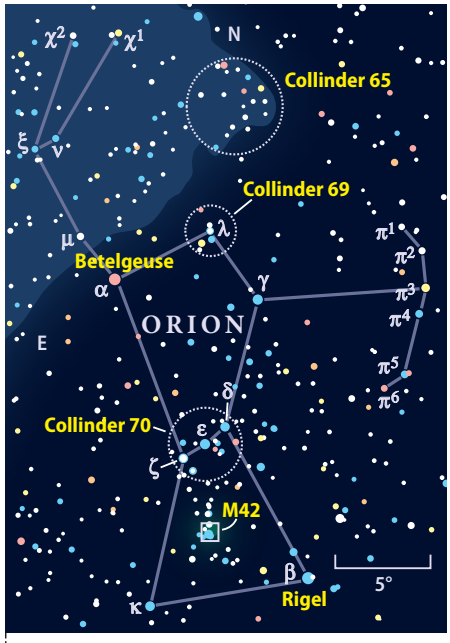
This month marks the start of my

stellar astronomy course, which I teach every spring semester at Dowling College on Long Island. Often, a student will come up to me before the first class and ask, "So, what's this class all about?" My answer? "Orion!" I usually get a perplexed look back, but the fact is that much of the semester can be condensed into that single constellation. Orion is a "mine of wonders; this great constellation embraces almost every variety of interesting phenomena that the heavens contain," according to Garrett Serviss in his 1888 book *Astronomy with an Opera Glass*.

If you want to see star birth in action, look toward the middle star of Orion's "sword." That "star" is not a single sun at all, but rather a glowing cloud known as **M42**, one of the sky's busiest delivery rooms.

M42, also known as the Orion Nebula, is just the tip of an "iceberg" that engulfs nearly the entire constellation. As this giant cloud creeps from northwest to southeast, it is depositing pockets of newly formed stars in its wake. The wave is currently cresting near the sword. But to the north, the clouds have parted to reveal open star clusters. All three of Orion's "belt" stars, along with another hundred or so fainter suns, belong to that cluster, known as **Collinder 70**. Swedish astronomer Per Collinder (1890–1974) first identified this object as a cluster in his 1931 catalog. Many of the 471 open clusters that Collinder included in his catalog are too large and sparse to appreciate through most telescopes, but are perfect for binoculars.

Most of Collinder 70's stars shine brighter than 9th magnitude, within range of 50mm binoculars from suburban skies.



ORION THE HUNTER showcases stars in various life stages: birth, adolescence, and old age. *ASTRONOMY:* ROEN KELLY

When you look their way, consider that those stars are probably less than 10 million years old. That's young compared to our 4.5-billion-year-old Sun, but much older than the stars in the Orion Nebula, which date back no more than 300,000 years.

Overall, three belt stars mark the width of Collinder 70. A distinctive S-shaped chain of 11 faint stars snakes from Mintaka, the belt's western star, to Alnilam at its center.

Follow the trail of star formation north, to Orion's triangular head. The triangle's top star (Lambda [λ] Ori), along with several dozen fainter suns within about 1°, all belong to **Collinder 69**. Most binoculars reveal between 15 and 20 stars ranging in brightness from 5th to 9th magnitude. Studies also show Collinder 69 is probably no more than 10 million years old.

A third Collinder cluster, **Collinder 65**, spills into adjacent Taurus. By adding a few non-cluster stars to the east and north, I imagine this cluster as a spear that Orion is about to heave at the Bull. Orion's "spear" measures about 8° tip to tip, which makes it perfect for 7x binoculars.

So far, we have examined star birth and adolescence in the Hunter. What about the other end of the scale? For that, we need look no further than **Betelgeuse**. While many of Orion's stars are quite young, happily fusing hydrogen into helium within their cores, Betelgeuse has been there, done that. It exhausted its core hydrogen supply long ago, causing the star to swell into an enormous red supergiant. Today, heavier elements are undergoing fusion in its core. Eventually, that process will end, and Betelgeuse will go out in a burst of glory as a supernova. For now, enjoy its brilliant copper red color, which indicates a surface temperature of about 6,000° Fahrenheit (3,300° Celsius). Contrast that to **Rigel**, which is a blue-white giant star. Rigel's surface temperature is estimated to be an incredible 36,000° F (20,000° C).

Next month, we'll play fetch with one of Orion's faithful dogs. Until then, remember that two eyes are better than one.

ONLINE EXTRA Examine a trio of objects in Orion at www.astronomy.com/toc.

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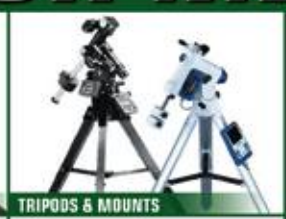

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Moon shot In November, India announced plans to launch its first piloted space mission by 2014 and land astronauts on the Moon by 2020.

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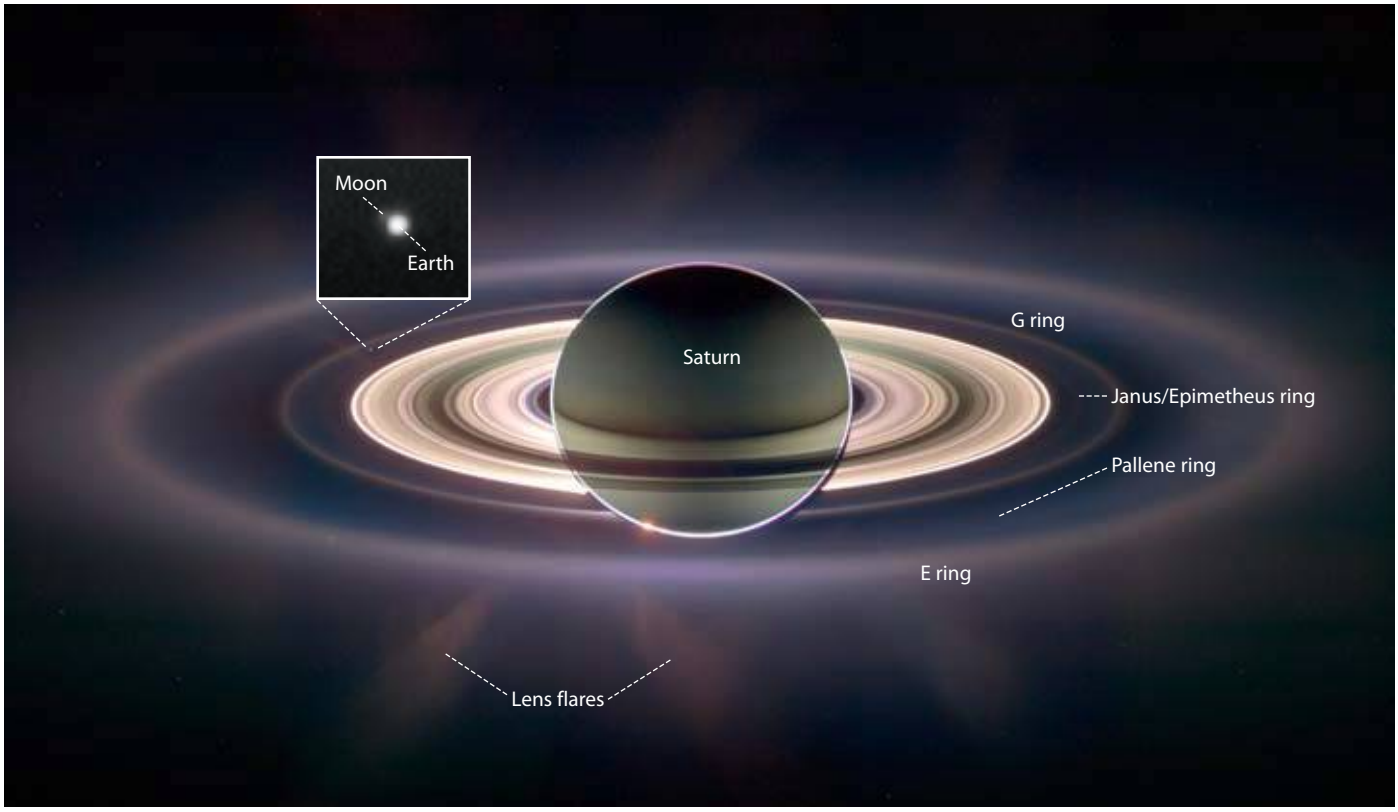


NASA/JPL/SSI

DUST UP. **Fine dust in Saturn's rings lit up when the Cassini probe spent 12 hours in the planet's shadow. Cassini discovered two new rings and imaged Earth and the Moon from nearly a billion miles away.**

25 Shuttle will fly to Hubble
26 Cassini captures golden Saturn
27 NASA to develop mission ideas
28 Solar sail may fly again

Cassini views backlit Saturn, sees Earth and Moon

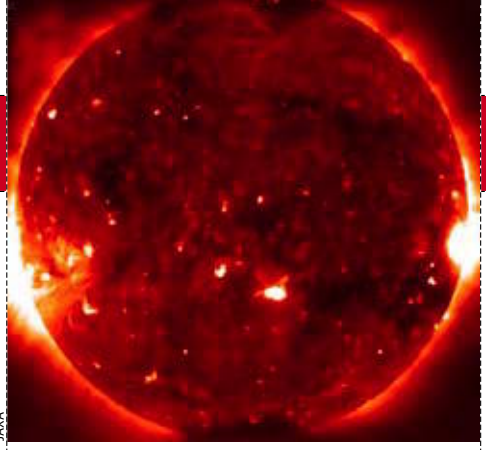
On September 15, 2006, NASA's Cassini spacecraft spent 12 hours in Saturn's shadow. With the giant planet acting as a sunshade, Cassini viewed the rings as never before, revealing two faint, previously unknown rings and glimpsing its home world.

During 3 hours, Cassini's wide-angle camera snapped 165 visible-light, ultraviolet, and infrared images as the spacecraft drifted in shadow approximately 1.3 million miles (2.2 million kilometers) from Saturn. The dark journey allowed the probe to observe the microscopic particles that comprise Saturn's faintest rings. Micron-sized dust particles brighten when viewed with the Sun behind them.

In places, the composite overexposes the bright rings visible from Earth. The two newfound rings coincide with the orbits of small moons. A 3,100-mile-wide (5,000 km) dust band marks the shared orbit of Janus and Epimetheus. The other new ring, about 1,550 miles (2,500 km) across, matches the orbit of Pallene, which Cassini found in 2004.

Looking back toward the Sun, Cassini's exposures also captured Earth and the Moon, both nearly a billion miles away.

— FRANCIS REDDY



JAXA

QUIET SUN. **Japan's Hinode imaged the X-ray Sun in unprecedented detail October 28.**

First light for "Sunrise"

The Japanese solar-observing satellite Hinode ("sunrise") returned its first images in late October. Formally known as Solar-B, the craft sports X-ray and optical telescopes and an extreme-ultraviolet spectrograph.

Shortly after launch September 22, 2006, the front door of Hinode's X-ray telescope (XRT) opened prematurely. Unexpectedly high tube temperatures initially alarmed controllers. But, on October 23, XRT images of the Sun displayed the instrument's exceptional (nearly 1") resolution. The instrument imaged magnetic-loop details in X-ray hot spots for the first time. — **F. R.**

SETI Institute opens Carl Sagan Center

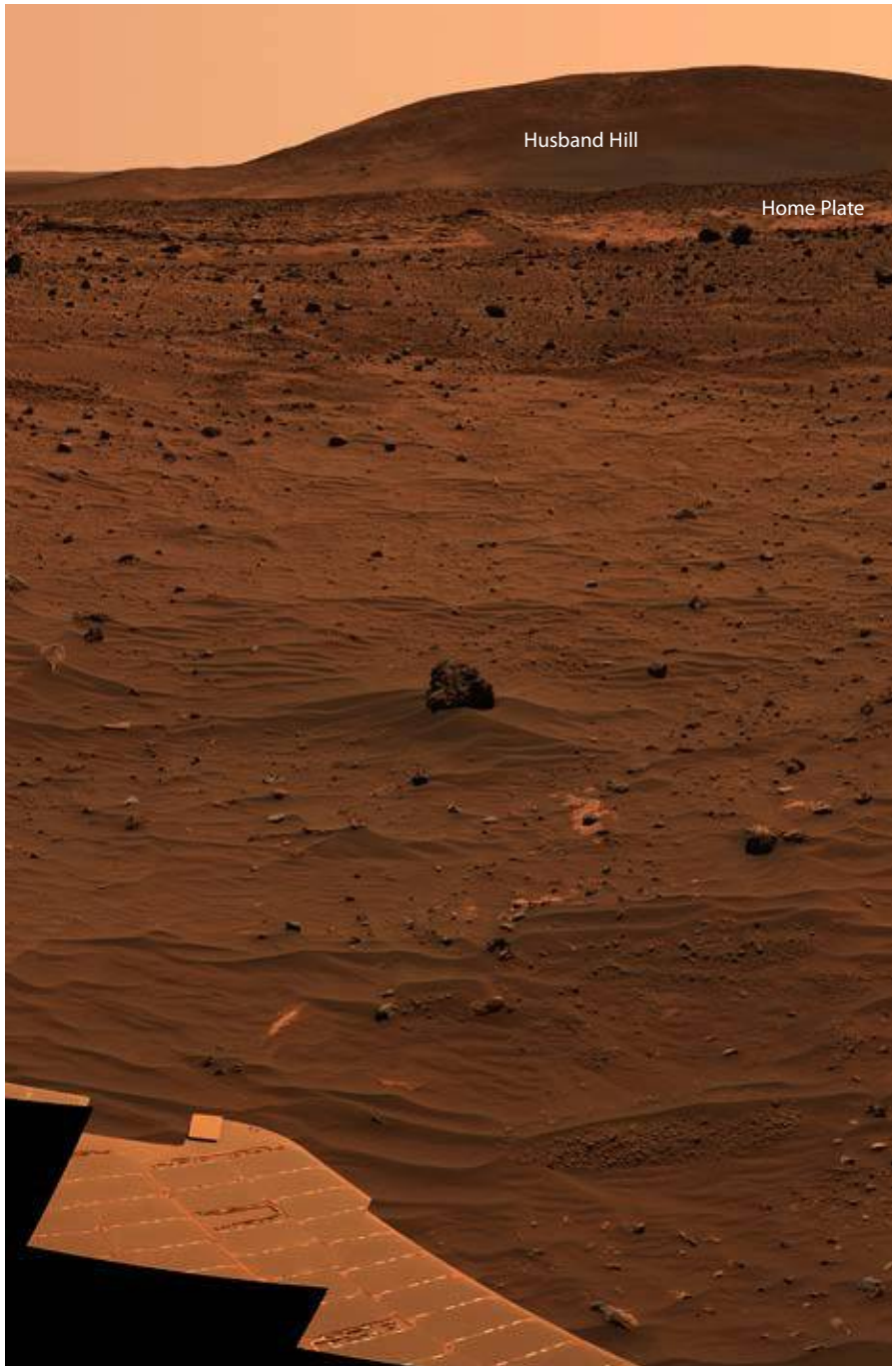
NASA's proposed 50-percent cut in 2007 astrobiology funding is a "clear reminder of how volatile government support for science can be," says Scott Hubbard of the SETI Institute. So, on October 17, the Mountain View, California, research group opened its Carl Sagan Center for the Study of Life in the Universe.

"It is our intention to create new partnerships and seek new sources of funding, including private philanthropy, to weather the cycles inherent in the governmental funding process," Hubbard says.

Named for astronomer Carl Sagan, the center staffs 50 scientists. "Carl would have been thrilled that this new center, devoted to pursuing the scientific questions that fascinated him most, will bear his name," says Ann Druyan, Sagan's widow. — **F. R.**

Movin' out

A 3-year Hubble Space Telescope study shows dark energy has been speeding up cosmic expansion for at least 9 billion years.



NASA/JPL/CORNELL

BATTING 1,000. **A portion of Spirit's "McMurdo Panorama" shows Husband Hill, which the rover summited in 2005, and the light-colored volcanic rock of Home Plate.**

Rovers clock 1,000 martian days

Spirit and Opportunity, NASA's Mars Exploration Rovers, have drilled, dug, and rolled across Mars for more than 1,000 martian days — more than 11 times their design lifetimes. Scientists celebrated the feat by directing Spirit's cameras to collect images for its most detailed martian panorama yet.

Spirit captured the 360° "McMurdo Panorama" while parked at its winter haven, angled to maximize sunlight on its solar panels. Spirit began shooting the images during its 814th martian day, or sol, on April 18, 2006. The rover completed the project on sol 932 (August 17, 2006). — **JEREMY McGOVERN**

ESA

GRAVITY MAP. **ESA's GOCE satellite will map Earth's gravitational field in 2007.**

ESA mission to explore Earth's gravity

Later this year, the European Space Agency (ESA) plans to launch its Gravity Field and Steady-State Ocean Circulation Explorer (GOCE). The mission is ESA's first satellite dedicated to measuring Earth's gravity field.

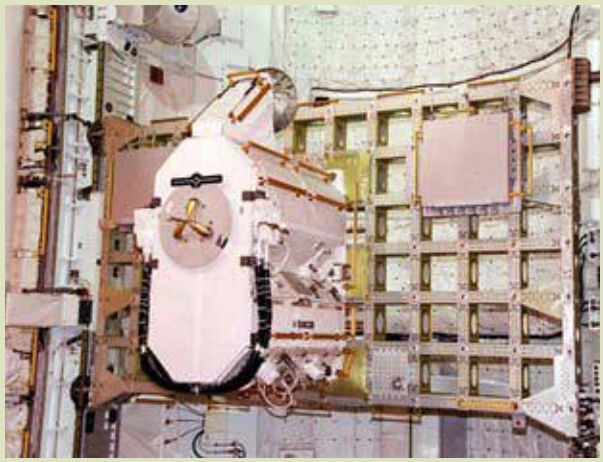
The force of gravity actually varies across Earth's surface. Our rotating planet flattens at the poles, making gravity stronger there, and bulges out at the equator, which reduces gravity's pull. The distribution of matter beneath Earth's surface also alters gravity's attraction.

Scientists say GOCE will determine the dips and crests of Earth's gravity field to unprecedented precision. The data will give geologists new insights into changes occurring within our planet.

For instance, Canada and Scandinavia were once covered by thick, heavy ice sheets. With this mass gone, land in these areas rises by up to 0.8 inch (2 centimeters) a year. GOCE data will also help scientists improve their understanding of important ocean currents. — **F. R.**

Waste management: Just throw it out

By the middle of this year, the International Space Station (ISS) may have a free-flying companion satellite in a nearby orbit. But this won't be a tiny bolt or a show-off golf ball or a dropped tool. This new companion will be big. Its size will make it an attractive target for amateur satellite observers, a hazard for space navigation, and a potential threat for Earth dwellers.



NASA

SHOVE OFF. **Later this year, astronauts will push this 1,500-pound (680 kilograms), refrigerator-sized ammonia tank off of the space station.**

NASA calls the unit the External Ammonia Supply (EAS). In 2001, astronauts installed it on ISS, where it served as a backup supply of coolant fluid for the station's thermal control system. The fluid carries unwanted heat to the station's large radiators, which dispel the energy into space.

Imagine a pipe rupture or other damage interrupted the regular coolant supply. Astronauts would have to shut down most of the station's heat-producing electronic equipment until the damage was repaired and the EAS refilled the coolant system.

On STS-116 early in 2007, astronauts will install a permanent thermal system with built-in reserves on ISS. At that point, the EAS will be obsolete and must be removed from the station.

The EAS weighs 1,500 pounds (680 kilograms) and is about the size of a household refrigerator. It was supposed to return to Earth on a shuttle mission, but NASA's reduction in flight opportunities has squeezed it out of the official manifest. Instead, if NASA approves current plans, astronauts will just throw the EAS away.

The safest way to do so is to manually push it away from the station in precisely the right direction. If pushed lightly opposite the station's motion, it will fall behind and below ISS, slip into a lower but faster orbit, and pass safely beneath. Month by month, it will continue to fall, never threatening a collision with ISS.

But spacecraft on their way *up* to the station will have to know where the EAS is so they can steer clear of it.

Astronauts have been practicing "safe separation" for about a year in test and training facilities at NASA's Johnson Space Center in Houston. The shove-off crew member will stand on a platform attached at the end of the station's robot arm, while another astronaut detaches the EAS from its restraint bolts. Once free, the astronaut on the robot arm will gently push the unit with both hands toward the back end of the station. Too forceful a push will overload the safety hinge of the arm's platform and make it fold away; with too gentle a push, the unit may not clear all of ISS' structures on its way out.

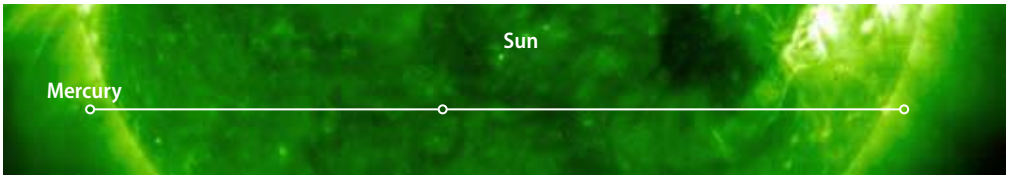
Calculations show a 2-inch (5 centimeters) per-second push at an angle plus or minus 30° to ISS' orbit will be adequate for safety. Astronauts regularly have achieved rates up to 4 times faster with much tighter angular precision.

And then, for the next year or more, skywatchers on Earth will be able to see the EAS as a magnitude 2 or 3 "star" either leading or trailing ISS. It will eventually burn up in the atmosphere, although the EAS' size makes it possible some pieces will survive to reach the ground.

In the months ahead, these plans will be modified further, including the possible addition of other disposable hardware to the ISS cleaning. In the following months, amateur astronomers will be able to watch the ISS companion "lap" the station repeatedly as the EAS slips closer and closer to Earth. — **JAMES OBERG**

Troubled MGS

Controllers lost contact with NASA's Mars Global Surveyor spacecraft November 5, a few days after it reported trouble with a solar panel.



NASA/ESA

TINY TRANSIT. The SOHO spacecraft's Extreme ultraviolet Imaging Telescope captured this view of Mercury's solar passage November 8.

Sunwatchers spy Mercury transit

Observers from Canada to China enjoyed a rare glimpse of planetary shadow play. On November 8, the planet Mercury was visible in silhouette as it slid across the Sun's face. The event, called a transit, lasted about 5 hours as Mercury, which orbits the Sun in just 88 days, laps Earth.

But amateur astronomers weren't the only ones watching. Sun-observing satellites like NASA's Transition Region And Coronal Explorer (TRACE), Japan's newly orbited Hinode, and the joint NASA/ESA Solar and Heliospheric Observatory (SOHO) also monitored the event.

For Bernhard Fleck, SOHO project scientist at NASA's Goddard Space Flight Center in Maryland, the transit offered an opportunity to learn more about the instruments on the 11-year-old orbiting spacecraft. "SOHO's instruments should show Mercury as a completely black dot. It doesn't take a rocket scientist to see that's not the case," he says. Light scattered inside SOHO's instruments contaminates the planet's shadow. Transit observations offer a way for scientists to measure this effect and correct for it in images.

Jay Pasachoff at Williams College in Massachusetts hopes TRACE and Hinode data will confirm his ideas about the so-called black-drop effect. This optical illusion, in which a dark thread appears attached to a transiting planet after its disk has moved onto the Sun, stymied 18th- and 19th-century astronomers. Its visibility depends in part on how sharply a telescope brings light to a point, but Pasachoff says other causes influence it as well.

This was the second of 14 Mercury transits this century. The next one occurs in 2016. — **F. R.**

Shuttle will fly to Hubble

NASA Administrator Michael Griffin announced October 31 the space agency will fly a servicing mission to the ailing Hubble Space Telescope. The mission will replace failing gyroscopes and batteries to keep the instrument working through 2013.

"While there is an inherent risk in all spaceflight activities, the desire to preserve a truly international asset like the Hubble Space Telescope makes doing this mission the right course of action." Griffin says analysis of recent shuttle flights shows Hubble can be serviced safely.

NASA

SCOPE SERVICE. The Hubble Space Telescope gleams in shuttle Columbia's payload bay in 2002, when astronauts last visited.

Veteran astronaut Scott D. Altman, who helmed the scope's last servicing mission, will command the next repair flight, which will launch no sooner than May 2008. Astronauts will install two new instruments: the Cosmic Origins Spectrograph (COS) and Wide Field Camera 3 (WFC3). They will also try to fix the Space Telescope Imaging Spectrograph (STIS), which stopped working in 2004. — **F. R.**

QUICK TAKES

LUNAR "TOP 30"

China marked the October 6, 2006, Moon Festival by announcing a 30-song play list for the nation's first lunar satellite, Chang'e 1. The probe will broadcast its tunes to Earth in 2008.

FRESH AIR

In November, the European Space Agency (ESA) delivered to NASA experimental hardware to analyze air quality on the International Space Station (ISS). The Analyzing Interferometer for Ambient Air (ANITA) simultaneously scans for 32 contaminants. It will launch aboard ESA's Automated Transfer Vehicle later this year.

SHUTTLES DELAYED

NASA has pushed back the year's first three shuttle launches. STS-117 will fly no earlier than March 16, STS-118 will launch June 28 or later, and STS-120 will lift off no earlier than September 9. The availability of modified external tanks played a role in the decision.

NO WAY OUT

NASA planners for the Opportunity rover say they've found a safe way into 200-foot-deep (60 meters) Victoria Crater, but no way out yet. A journey into the crater seems likely, even if it means a one-way trip for the rover.

ALDRIN: GO FOR MARS

"Mars is more habitable than any other place in the solar system," said astronaut and moonwalker Buzz Aldrin. He spoke at Chicago's Adler Planetarium November 9 to dedicate an exhibit on his Gemini 12 mission. "Sooner or later, we'll establish the beginnings of a settlement there," he predicted.

FAST ELECTRONS

Astronomers using NASA's Chandra X-ray Observatory have mapped where the Cassiopeia A supernova remnant accelerates electrons to cosmic-ray energies. — **F. R.**

A fistful of astronomy

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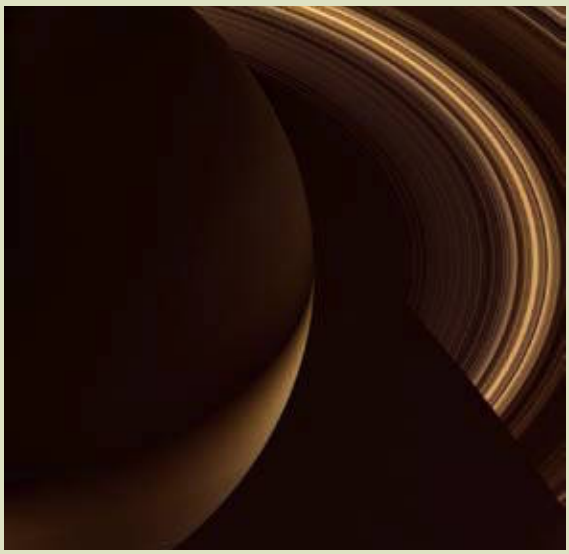
THESKY Pocket Edition

Cassini captures golden Saturn



NASA/JPL/SSI

TAWNY RINGS. Sunlight scattered in Saturn's rings and atmosphere creates a surreal golden gleam.

Saturn's B and C rings shone in diffuse, scattered light as the Cassini spacecraft scanned the planet's night side September 28. Sunlight reflecting off the rings lights Saturn's southern hemisphere. The north shines feebly in the dim light that filters through the rings.

This golden-hued Saturn is a natural-color view. Cassini's camera is pointing toward the Sun, and the increased scattering from particles in the rings and atmosphere create the unique coloration. The spacecraft was 900,000 miles (1.4 million kilometers) from Saturn. — **F. R.**

February 1982

25 years ago in *Astronomy*

The 1979 Voyager Jupiter flybys whet planetary scientists' appetites for a longer look. In *Astronomy*'s 1982 cover story, "Galileo: Mission to Jupiter," scientists Clayne Yeates and Theodore Clarke gave a preview to NASA's Jupiter orbiter.

Originally slated for launch aboard the space shuttle in April 1985, the project suffered a series of delays — including launch hiatus following the 1987 loss of space shuttle Challenger. When the probe launched in 1989, safety concerns forced it to follow a less direct route to the giant planet than the Voyagers. And the craft never fully deployed its high-gain antenna, a problem that slowed communication.

Even before it arrived, Galileo returned the first close-up images of an asteroid, discovered that asteroids can possess gravitationally bound moons, and captured images of a comet impacting Jupiter. The probe it dropped into the giant planet provided the first direct "taste" of an outer planet's atmosphere. Galileo's rocky road ended in great success.

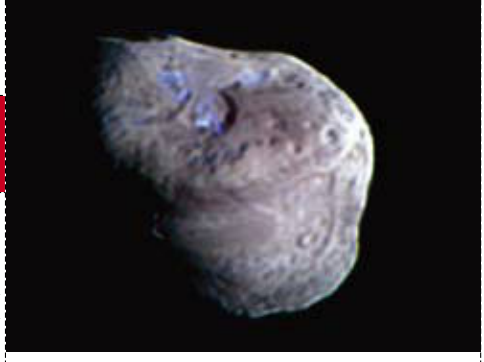
10 years ago in *Astronomy*

February 1997

"What are the most impressive structures in the night sky?" University of Rochester astrophysicist Adam Frank asked this question in *Astronomy*'s February 1997 cover story, "Blowing Cosmic Bubbles." His answer: bipolar nebulae.

These twin-lobed structures form in a variety of physical situations. They puff around aging Sun-like stars as planetary nebulae, shape dust and gas after stars like Eta Carinae undergo outbursts, and swaddle superhot Wolf-Rayet stars as they prepare to go supernova. No matter how different they are, each holds a fossil record of a star's past behavior — a resource invaluable to astronomers.

Philosophers have long pondered the relationship between truth and beauty. Says Frank: "Perhaps someone should tell them about bipolar nebulae." — **F. R.**



NASA/UM/SAIC

TARGET SWAP. **NASA is considering sending its Stardust spacecraft to image the crater the Deep Impact mission blasted into Comet Tempel 1 in 2005.**

NASA to develop mission ideas

On October 30, NASA chose six proposed missions for concept studies as part of its Discovery program. The first, headed by the University of Arizona's Michael Drake, is the Origins Spectral Interpretation, Resource Identification, and Security (OSIRIS) mission. It would return surface samples from near-Earth asteroid RQ36, which measures roughly 1,900 feet (580 meters) wide.

The space agency's second pick is the Venus Sounder for Planetary Exploration (Vesper) orbiter, designed to investigate Venus' atmospheric composition and dynamics. Gordon Chin of NASA's Goddard Space Flight Center in Maryland would lead the project.

Maria Zuber of the Massachusetts Institute of Technology will helm the Gravity Recovery And Interior Laboratory (GRAIL) Moon mission. The craft would map lunar gravity in detail to reveal our satellite's internal structure.

NASA also selected three "missions of opportunity" that would re-task spacecraft launched for other purposes. The Deep Impact eXtended Investigation (DIXI) mission would direct the Deep Impact spacecraft, which flew past Comet Tempel 1 in 2005, to Comet Boethin. Deep Impact also figures in the Extrasolar Planet Observations and Characterization (EPOCh) proposal, which would watch for transits of Earth-sized planets around other stars.

Finally, the Stardust spacecraft, which flew past and returned samples of Comet Wild 2, may be tasked to fly by Comet Tempel 1 and observe changes there since 2005. **— J. M.**

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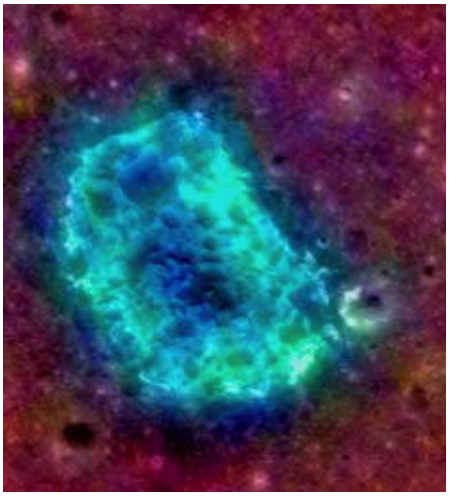
Icy seesaw Antarctic ice cores confirm a theory that warming and cooling periods seesaw between Earth's north and south polar regions, thanks to changes in ocean currents.



PETER SCHULTZ (BROWN UNIVERSITY)

LAST GASP. **Freshly exposed rock (blue) marks the Moon's Ina structure, which may be venting gas today.**

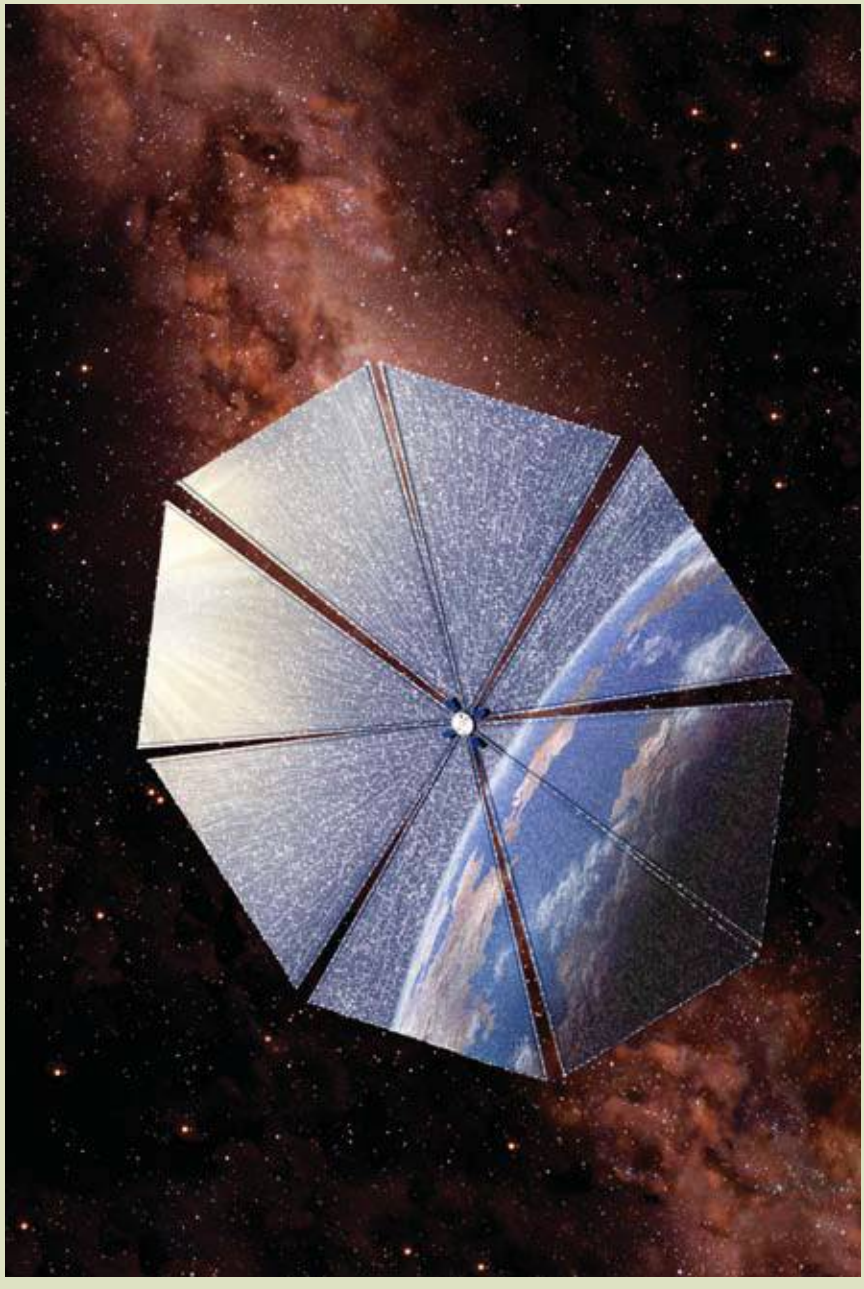
Ina suggests the Moon is still active

Scientists studying a lunar caldera named Ina say it has vented gas in the last 10 million years — and may be doing so today.

Brown University's Peter Schultz led the team. Ina is a D-shaped depression about 1.2 miles (2 kilometers) wide located in Lacus Felicitatis (19° N, 50° E). The structure stood out to orbiting Apollo astronauts, who noticed its distinctly bluish tint.

Brown says the most detailed images of Ina show terrain with sharp edges. The constant rain of meteoroids on the Moon should wear down such terrain. The team found only two impact craters larger than 100 feet (30 meters) on the 3-square-mile (8 square km) structure. Finally, rock exposed to space darkens and reddens with time, but Ina is bright and blue.

Schultz thinks a rush of gas from deep within the Moon vented through Ina, scoured surfaces, and exposed fresh rock. He'd like to see professional and amateur astronomers start a coordinated observing campaign to search for such activity. Gas-lofted dust could remain visible for as long as 30 seconds. "With modern alert networks, that's long enough to move a professional telescope into position to see what's happening," he says. **— F. R.**



RICK STERNBACH (THE PLANETARY SOCIETY)

TRY AGAIN. **A solar sail may make an ideal space-weather station.**

Solar sail may fly again

The Planetary Society, a nonprofit group that promotes space exploration, hopes to re-fly its Cosmos 1 solar sail, which uses sunlight alone to maneuver in space.

"We continue to pursue the dream of flight by light," says Louis Friedman, the society's executive director. "Funding, not technology for solar sailing, remains our largest hurdle."

NASA is considering a prize to demonstrate solar sailing for a mission to the gravitational balance point between Earth and the Sun. Such a mission may actually be easier to fly than navigating a solar sail in low Earth orbit, Friedman says.

The society launched Cosmos 1 June 21, 2005, from a Russian submarine, but the vehicle never reached orbit. **— F. R.**

NASA invests in Red Planet

NASA is taking an innovative approach to innovation. On September 20, the space agency announced it created and will fund a nonprofit venture capital firm. Called Red Planet Capital, Inc., the fund will invest government money in small, cutting-edge aerospace and biomedical companies. NASA hopes the move will help it tap into new technologies.

"Our focus is not on today or near tomorrows, since nothing from these new companies can be used before at least the 3-to-5-year time frame," Peter Banks, one of the fund's managers told *The Washington Post*. Instead, the fund sets a technological path toward human trips to Mars.

This is the government's third experiment with venture funds, following efforts sponsored by the CIA and the Army. In fact, a former head of the CIA's In-Q-Tel fund is NASA chief Michael Griffin. — **F. R**

U.S. cosmologists win Nobel Prize

The 2006 Nobel Prize in physics went to two American cosmologists, the Royal Swedish Academy of Sciences announced October 2. George Smoot of Lawrence Berkeley National Laboratory in Berkeley, California, and John Mather of NASA's Goddard Space Flight Center in Greenbelt, Maryland, will split the $1.4 million prize.

Both scientists were instrumental in the success of NASA's Cosmic Background Explorer (COBE). In 1989, the satellite was the first to detect faint temperature variations in the cosmic microwave background (CMB), the remnant radiation of the Big Bang. "I think of it as the accumulated trace of everything," says Mather.

COBE's all-sky map of these temperature variations has been called the universe's first "baby picture." "It's like looking at an embryo that's a few hours old," says Smoot. — **F. R.**

NASA/JPL/ASU

KNIFE CUT. Magma may have forced its way through a long, straight fault to produce Mars' suture-like Galaxias Fossae.

Mars scar may mark magma dike

Galaxias Fossae slices 250 miles (400 kilometers) across Mars' Utopia Planitia like a scar from planetary surgery. That first impression may not be so far off.

Unlike many channels on Mars, Galaxias Fossae may trace a volcanic dike. A dike is what geologists call a ribbon of molten rock that forces its way into and widens a fault in rock near the crust. The rising magma in neighboring volcanoes ballooned the crust, which stretched and cracked. A thin ribbon of molten rock forced its way into this fault and forced magma near the surface. The hot rock in the fault melted ice and permafrost in the ground above, which then collapsed along its course.

This image, colorized to resemble Mars, is a mosaic of photos taken at visible wavelengths by the THEMIS camera on NASA's Mars Odyssey orbiter. — **F. R.**

BRIEFCASE

Star blast

A December 2005 flare from the binary system II Pegasi burst forth with 100 million times the energy of a typical solar flare.

Using data from NASA's Swift satellite, Drake Demming and Rachel Osten of NASA's Goddard Space Flight Center report the first direct evidence that these stellar flares accelerate particles in ways similar to mechanisms seen on the Sun. Their study will appear in an upcoming issue of *The Astrophysical Journal.* — **F. R.**

Shake-up

The observatories atop Hawaii's Mauna Kea escaped largely unscathed from a pair of earthquakes October 15. The 6.7-magnitude temblor and its 6.0-magnitude aftershock were the largest quakes to strike the Big Island in 20 years.

The shaking snapped a ceramic rod supporting sensors in the Gemini North Telescope's secondary mirror system. The damage put the scope out of commission until November 11. — **KATE MEREDITH**

3-D CMEs

NASA launched its twin Solar TErrestrial RElations Observatory (STEREO) on October 25. One craft leads Earth in its orbit around the Sun, the other follows. From separate vantage points, the spacecraft will image the Sun's powerful coronal mass ejections (CMEs).

"We're going to be able to ... get depth perception on these CMEs in ways that we have never been able to before," says Jim Adams, STEREO's deputy project manager. — **TRACY STAEDTER**

What if string theory is

If it is, then dark matter, dark energy, and cosmic inflation are in big trouble. /// BY STEN ODENWALD

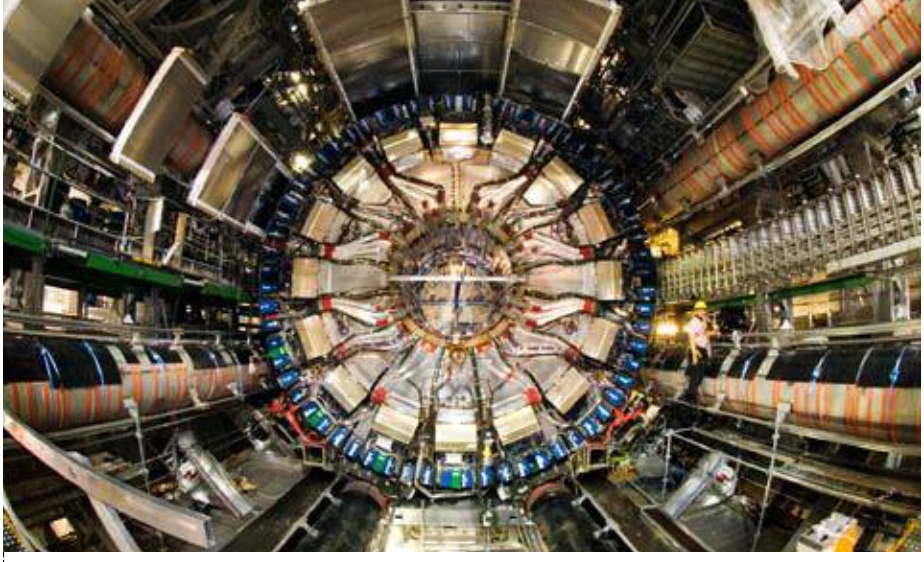
Scientists pin their hopes of unifying nature's fundamental forces to a single concept crafted over the course of 3 decades by thousands of mathematicians and physicists. It's called superstring theory.

Its basic ingredients are one-dimensional strings of pure energy that exist in a 10-dimensional universe, four of which are our familiar spatial dimensions plus time. Strings' vibration and movement create the fabric of space itself, along with all of nature's fundamental forces and elementary particles.

Now, imagine a future in which physicists are delivered the bad news: irrefutable data proving superstring theory doesn't work in our physical world. We're nowhere near such a crisis today, but it's sobering to realize what we stand to lose if physics' best bet proves to be a complete dead end.

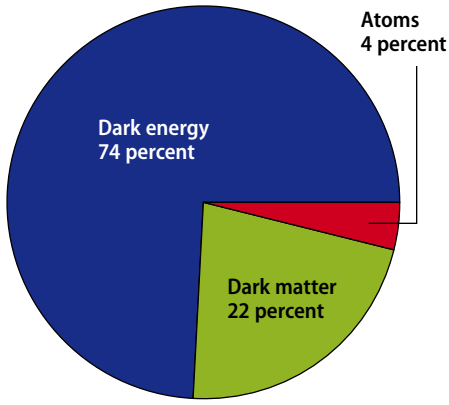
WRONG?

IF SCIENTISTS' IDEAS about supersymmetry are right, every elementary particle has a massive superpartner not yet detected. Scientists hope to detect some of these particles when the Large Hadron Collider begins smashing atomic nuclei in 2007. DON DIXON FOR *ASTRONOMY*



THE LARGE HADRON COLLIDER'S ATLAS detector, to be completed this year, will be the site where high-velocity proton beams collide. The resulting subatomic debris should reveal fundamental-particle processes. The ATLAS experiment is one of the largest collaborative efforts ever attempted in the physical sciences: 1,800 physicists from 150 institutions in 35 countries. CERN/CLAUDIA MARCELLONI

Cosmic constituents



COSMOLOGISTS' best tally of cosmic content comes from NASA's Wilkinson Microwave Anisotropy Probe (WMAP). Normal matter accounts for just 4 percent.
ASTRONOMY: ROEN KELLY

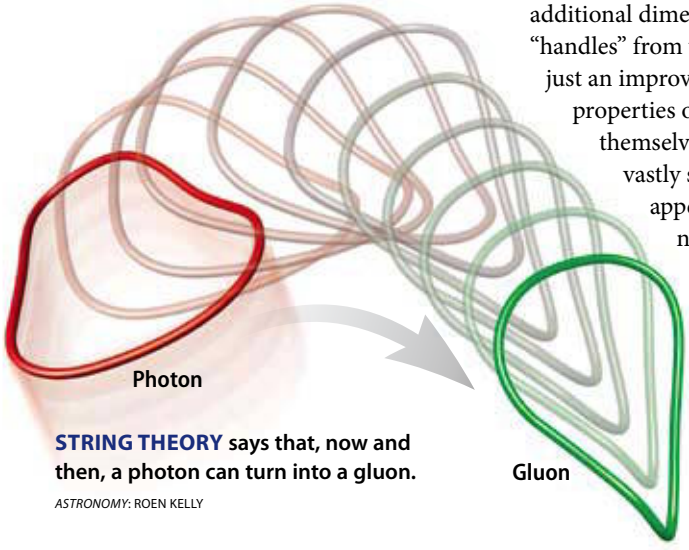
Extra dimensions

Superstring theory is based on three key ideas that remain experimentally unproven after 30 years of research: the principle of supersymmetry; additional spatial dimensions; and gravity as a force defined by the exchange of quantum particles.

Supersymmetry is a mathematical principle that allows force-carrying particles, such as photons and gluons, to transform into one another. It also allows the unification of gravity with other forces because its particle, which some call the graviton, can transform into one of the other force-carriers. Although this idea is mathematically elegant, and puts gravity on an equal footing with the other forces, no one has ever detected, for example, a photon turning into a gluon. Luckily, other ways to search for supersymmetry exist.

If nature follows supersymmetry, then every normal particle has a superpartner: Electrons partner with "selectrons," photons with "photinos," quarks with "squarks," and so on. These superpartners haven't been seen yet, but a new accelerator, called the Large Hadron Collider (LHC), is being built in Switzerland to find them. Researchers hope at least a few of the lightest superparticles will turn up when the LHC begins operation later this year. Such a success would be a prelude to confirming the most bizarre physics idea of the last 80 years — extra dimensions to space.

Identity change



STRING THEORY says that, now and then, a photon can turn into a gluon.
ASTRONOMY: ROEN KELLY

Space-time is just the start

Conventional superstring theory requires extra dimensions to space beyond the usual three (up-down, left-right, near-far). These additional dimensions give physicists extra "handles" from which they can fashion not just an improved theory of gravity but the properties of the known particles themselves. These extra dimensions, vastly smaller than a proton, appear as six additional coordinates attached to each point in normal space.

They actually form their own closed, six-dimensional spaces that must be everywhere — otherwise, particles would take on different properties as they move through our three-dimensional world. There are trillions of possible six-dimensional geometries, each calling into existence a unique universe with specific physical laws, particles, and forces. Which one is ours?

Some researchers feel all geometric possibilities exist in the multiverse — the collection of all possible universes with all possible physical laws logically allowed by superstring theory. Ours, then, is a Goldilocks Universe, where exactly the right six-dimensional geometry allows the existence of life as we know it. There may be 10^{100} universes that fail this challenge. There may be others in which new, unthinkable possibilities for life could flourish.

If extra dimensions really exist, they'll change the behavior of gravity at small distances. In 2003, John Price at the University of Colorado and his colleagues announced an ultra-precise measurement of gravity at scales of one-tenth of a millimeter. The team saw no departure from gravity's inverse-square law, in which the force of attraction decreases by the square of the distance between bodies. So, the hunt resumes below this limit to test other extra-dimensional possibilities.

"We have a number of hints from experiments and theoretical ideas that make us think they're probably out there," says Joseph Lykken, a physicist at Fermi

Astronomer **Sten Odenwald** *works at NASA's Goddard Space Flight Center in Maryland and is investigating the cosmic infrared background.*

National Accelerator Laboratory in Batavia, Illinois. "That's why we're so excited about looking for them."

If scientists validate superstring theory, we'll see the birth of the first unified description of the physical world. Along the way, we'll have to make peace with the idea of a multiverse in which trillions of other universes may exist, each with its own natural laws, forces, and particles.

But, what would happen if all these ideas are wrong? String theory would go down in history as the most spectacular wrong-turn science has ever taken. It will have sent thousands of physicists on a spectacular wild-goose chase, while simultaneously revolutionizing obscure subjects in pure mathematics.

Forget supersymmetry?

If extra dimensions don't exist, then supersymmetry doesn't either. Without both of these cornerstones of string theory, physicists would be left with what they call the standard model.

The standard model combines electro-weak theory (EW) — itself a combination of electromagnetism and the weak nuclear force — with a separate theory of the strong nuclear force called quantum chromodynamics (QCD). Each part behaves like a train on a separate track. But just as electricity and magnetism were unified into electromagnetism, the standard model's EW and QCD are so similar that they, too, must be unified.

Grand unification theories (GUTs) tried to do just this. Physicists worked with dozens of prospects between 1975 and 1980; most failed. Many predicted the proton, the foundation of atomic nuclei, would rapidly decay; some introduced faster-than-light tachyons as new physical particles.

None turned out to work very well once physicists puzzled out their intricate mathematics and compared them to the real world. Physicist Mark Srednicki at the University of California, Santa Barbara, once complained about one candidate, "It is impossible to get this pile of junk to come out anything like the standard model."

In some respects, a world without superstring theory isn't so bad. The standard model and ordinary general relativity hold all astronomers need to describe accurately most of the phenomena they study, from galaxy evolution and supernova detonations, to the extreme physics of neutron stars and black holes.

As for unification, the late physicist Richard Feynman once said, "Perhaps it is difficult for physicists to unify gravity with the other forces because nature never intended for them to be unified in the first place."

Cosmic trouble

Astronomers have also discovered there is far more to the universe than what we can see. The standard model has absolutely no place in it for dark matter and dark energy, ingredients that constitute 96 percent of the universe's gravitating "stuff."

And it gets worse. Without supersymmetry, some physicists have proven that the energy of empty space would be so enormous the universe would instantly collapse.

Only by understanding physics beyond the standard model can we hope to understand how the vacuum works and the universe's dark side. And only string theory appears able to serve as a reliable mathematical guide to that larger universe.

Another major disaster to astronomy would be in our understanding of the largest structures in the universe, and the universe's large-scale smoothness revealed by studies of the cosmic microwave background (CMB).

Inflation, a super-fast expansion of the universe when it was less than a trillionth of a trillionth of a second old, explains observations of the CMB made by satellites such as NASA's Wilkinson Microwave Anisotropy Probe (WMAP). But it can't account for

LITERALLY trillions of possible six-dimensional geometries exist, each calling into existence a unique universe. Which one is ours?

STRING SPEAK

GENERAL RELATIVITY
Albert Einstein's formulation of gravity, which shows that space and time communicate the gravitational force through their curvature.

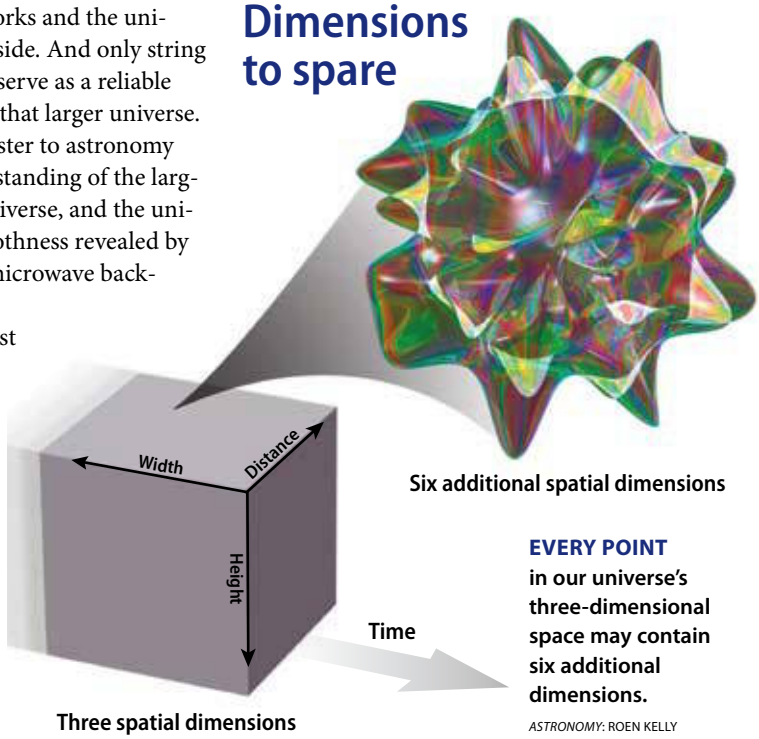
GLUON
The smallest bundle of the strong nuclear force, which holds atomic nuclei together.

QUANTUM MECHANICS
Laws governing the universe on atomic scales in which uncertainty and the dual nature of waves and particles become apparent.

STANDARD MODEL
A theory of interactions of nature's most fundamental known particles (e.g., electrons and quarks) developed in the late 1960s and early 1970s. Its inability to explain gravity suggests a more fundamental theory exists.

STRING THEORY
A unified theory of the universe postulating that the fundamental ingredients of nature are not particles but one-dimensional filaments called strings. String theory unites quantum mechanics and general relativity, which are otherwise incompatible; often short for superstring theory.

Dimensions to spare



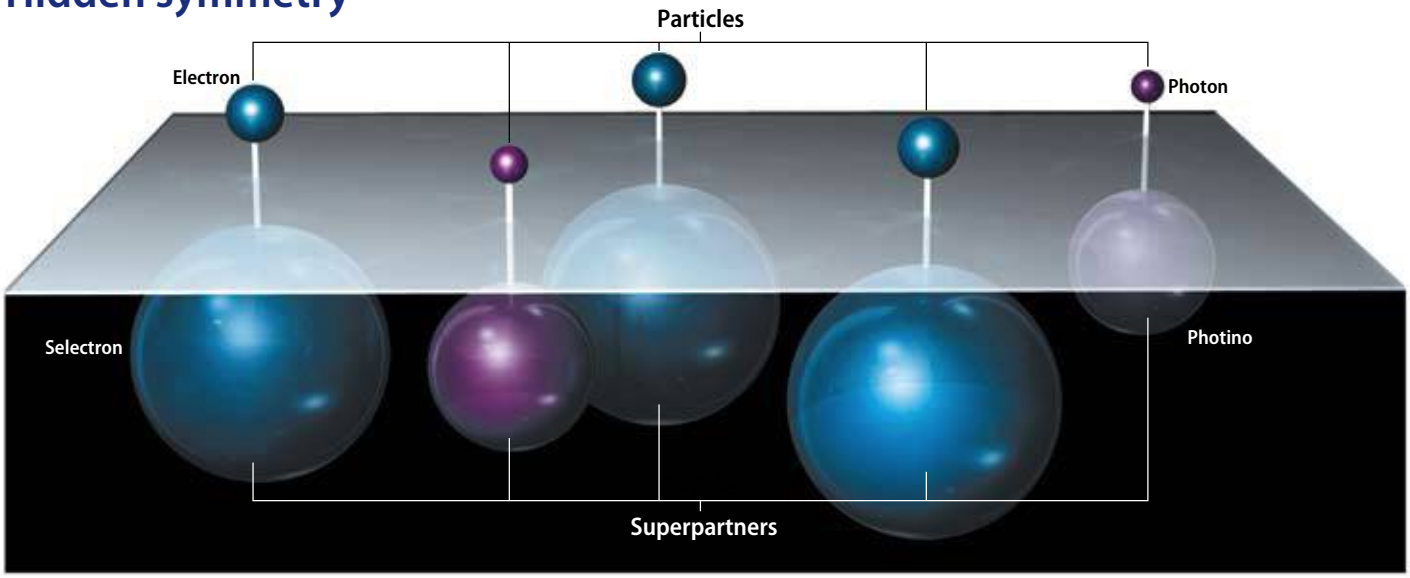
Six additional spatial dimensions

Three spatial dimensions

EVERY POINT in our universe's three-dimensional space may contain six additional dimensions.

ASTRONOMY: ROEN KELLY

Hidden symmetry

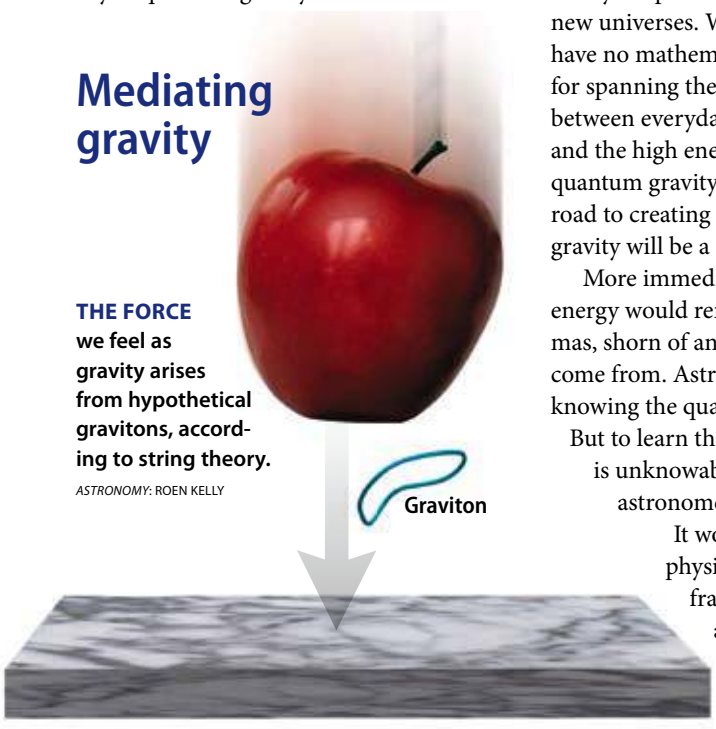


SUPERSYMMETRY envisions a "shadow world" that links known particles to massive superpartners not yet detected. *ASTRONOMY:* ROEN KELLY

the small-scale structure that led to galaxy formation. Only by reaching back to the era before inflation, often called the quantum-gravity era or Planck era, can cosmologists explain why today's universe looks the way it does at galactic scales.

The standard model and ordinary general relativity aren't enough. Only some larger, more encompassing, theory can lead the way. "It is hard to find a serious paper about particle phenomenology that doesn't in some way use the tools of superstring theory," says Stanford University physicist Leonard Susskind. "Furthermore, we all agree that the origin of elementary particles is most likely at the Planck scale and cannot be understood without a good theory of quantum gravity."

Mediating gravity



THE FORCE we feel as gravity arises from hypothetical gravitons, according to string theory. *ASTRONOMY:* ROEN KELLY

In the 1980s, when Alan Guth at Massachusetts Institute of Technology and Andre Linde at Moscow University first developed the inflation idea, it had nothing to do with string theory, extra dimensions, or supersymmetry. Since then, refinements to inflation scenarios have come only by borrowing ideas from superstring theory.

End game

Without superstring theory, we'd lose the intriguing philosophical prospects for the multiverse, with its infinite and eternal creativity in spawning new universes. We'd have no mathematics for spanning the gap between everyday physics and the high energies where quantum gravity operates. The road to creating a quantum description of gravity will be a murky one.

More immediately, dark matter and dark energy would remain imponderable enigmas, shorn of any clues about where they come from. Astronomers can live without knowing the quantum properties of gravity. But to learn that 96 percent of the cosmos is unknowable would be a bitter pill for astronomers to swallow.

It would be even worse for physicists. Without a logical framework in which to pose and answer questions, our inquiries into the fundamental aspects of the physical world would devolve into semantic quibbles. Other impacts prevent us from simply turning back the theoretical clock to the 1970s.

"We would be ignoring the vast amount of mathematical knowledge that has been gained over the subsequent years, mostly from string theory," Susskind explains. "That is just not going to happen. The changes in our theoretical understanding of quantum field theory, gravity, and black holes, are completely irreversible. The mathematics of superstring theory has even worked its way into nuclear physics and heavy ion collisions, as well as into condensed matter physics."

TO LEARN THAT 96 percent of the cosmos is unknowable would be a bitter pill for astronomers to swallow.

Historically, there are many examples of scientists forced to abandon ideas. Steady-state cosmology lasted nearly 30 years before science tossed it aside. While string theory is sparse on experimental validation, the situation is not so different from general relativity in its early days, when difficult mathematics made calculating a prediction extremely challenging.

In the 1980s, Princeton University physicist Ed Witten once described string theory as 21st-century physics inappropriately glimpsed long before its time. Let's hope it doesn't represent a bit of 25th-century mathematics, too.

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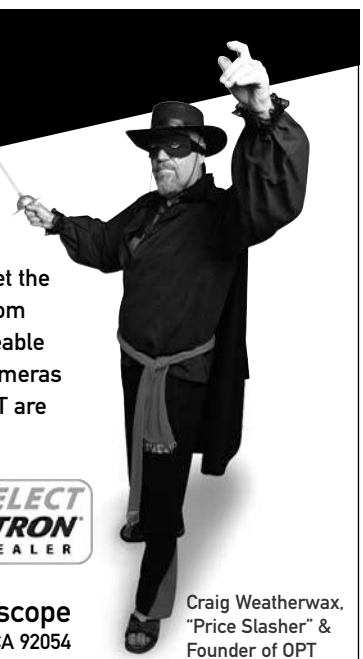

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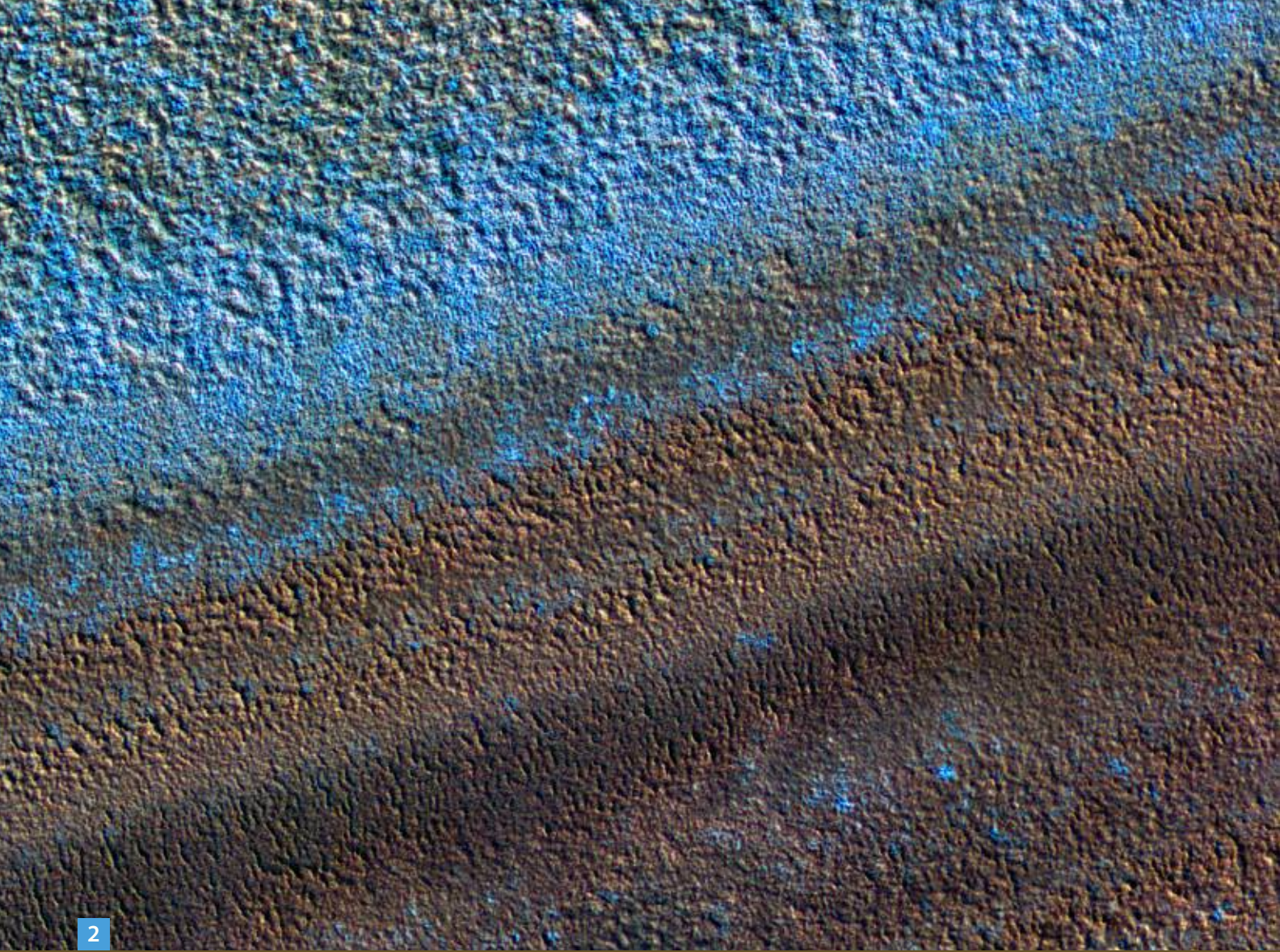
Mars like you've never seen it

The first color images from the Mars Reconnaissance Orbiter's high-resolution camera show details not much bigger than a bread box. /// BY ALFRED S. McEWEN

A new era in Mars exploration has begun. On September 29, the High Resolution Imaging Science Experiment (HiRISE) showed the world how well it can image the martian surface. Those of us familiar with the performance of both the camera and the Mars Reconnaissance Orbiter (MRO) spacecraft knew the first images would be spectacular. Many others, however, seemed surprised the images are so sharp and high in quality.



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1&2 THE NORTH POLAR LAYERED DEPOSITS preserve a record of past climate change on Mars. Clean water ice exists in the bright blue regions, while dust contaminates the ice in the brownish areas. The smallest features visible span approximately 3 feet (1 meter). NASA/JPL/UNIVERSITY OF ARIZONA

Although my HiRISE team has described many times the camera's expected performance in terms of pixel scale, signal-to-noise ratio, and point-spread function, peoples' eyes tend to glaze over when they read or hear such numbers. Fortunately, the images now can speak for themselves.

The idea that we can image features the size of a person while zipping by at 7,300 mph (12,000 km/h) surprises most people. In nearly all astronomical photography, a good image requires keeping the telescope steady and pointed at the target for some period of time. MRO/HiRISE actually needs to be whipping by to collect the best images.

We use a technique called Time Delay Integration (TDI). Each of our 14 CCD detectors are 2,048 pixels wide and 128 high. We image each piece of ground — an area only about 1 foot wide (30 centimeters) — up to 128 times. We then add together the signal from each of the 128 columns of pixels with just the right timing to precisely match the speed of the camera's field of view over the martian surface. The spacecraft must control its orientation so an object on the surface passes directly down each column of pixels.

Alfred S. McEwen *is the principal investigator for the Mars Reconnaissance Orbiter's High Resolution Imaging Science Experiment.*

If the TDI timing isn't exactly right, if the twist angle is slightly off, or if the spacecraft's pointing jitters, the images will be smeared. The credit for making all this work goes to the engineers — at Ball Aerospace in Boulder, Colorado, for building the camera, and at Lockheed Martin in Denver for building the spacecraft.

Mars now can show earthlings what a beautiful world it is. Although the images returned by the still-functioning Spirit and Opportunity rovers, as well as by the earlier Viking and Mars Pathfinder landers, are fascinating, all these missions explored flat, smooth places because only those are safe for landing. Elsewhere, Mars has rugged landscapes and beautiful formations worthy of being interplanetary parks.

We plan to shoot stereo images of the most intriguing regions and use them to derive detailed topographic models. Then, we can show what the terrain would look like to a person walking on the surface or flying low over the region in an

3

4

3 THE NORTHERN LOWLANDS span thousands of miles and show little topographic variation. The ice-rich patterned ground in this image also contains a circular pattern, perhaps a flattened impact crater. The smallest surface rocks visible measure only 1.5 feet across (0.5m). NASA/JPL/UNIVERSITY OF ARIZONA

4 MAWRTH VALLIS is one of many giant valleys that channeled water or ice into the northern lowlands billions of years ago. This segment of the stratified valley contains an orange unit on top of a dark blue layer, with a light-toned layer underneath. This final layer contains clay-rich minerals that almost certainly formed in water. The smallest features here span 1.5 feet (0.5m). NASA/JPL/UNIVERSITY OF ARIZONA

airplane. So far, we have just the original views from orbit, which look down from a distance of about 180 miles (300 km). But the local time of day on the martian surface, about 3:30 P.M., is ideal for photography. Plenty of light hits the surface, and shadows extend far enough to reveal the surface's shape.

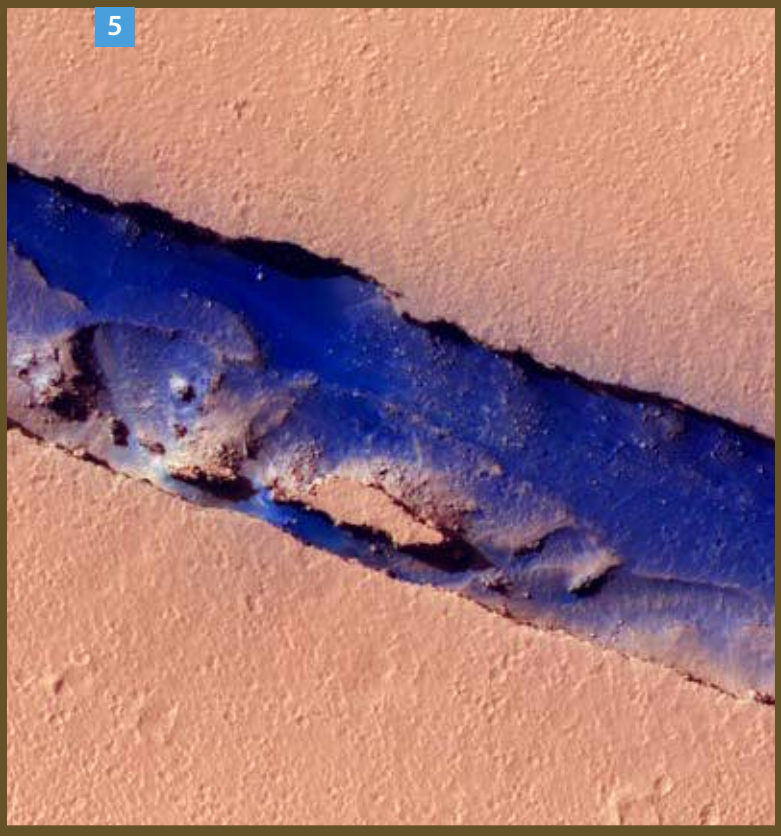
On these pages, we present color images of nine diverse martian regions. Most of the ones shown here are small samples of the full images. We have enhanced the colors to better show the normally subtle color variations. In the center stripe of each image, HiRISE has "color" vision composed of separate images acquired through blue-green, red, and near-infrared filters. We still have to complete our calibration procedures, however, so we can't yet correctly simulate natural color.

At the time these images were taken, in late September and early October, the northern hemisphere of Mars was in the midst of summer. The summer Sun exposes layered deposits in the north polar region by evaporating carbon-dioxide frost that builds up during the long martian winter.

HiRISE images (1 and 2) reveal complex surface textures and subtle color variations in the dust that mixes with water ice. These layered deposits contain a record of past climate change on Mars, much like ice cores from Greenland reveal the history of climate change on Earth. The challenge facing planetary scientists is to understand this record from remote observations alone.

Mars' northern lowlands hold great interest because the ground contains lots of ice that could be the remnants of past floods or of

5 A PROMINENT TROUGH cuts through the Cerberus Fossae rift system. The trough measures about 1,000 feet wide (300m) and 300 feet deep (90m). Dark sediments blanket the floor, and bright, dust-covered plains surround it. HiRISE resolves features about 3 feet across (1m) in this image. NASA/JPL/UNIVERSITY OF ARIZONA



6&7 IUS CHASMA represents a tiny portion of the Valles Marineris canyon system. This image shows just a small part of Ius Chasma's floor, replete with diverse rock types and dark sand that collected in low spots. Features as small as 1.5 feet wide (0.5m) show up, and the finest layers near the center of the close-up view (7) may be only inches thick. NASA/JPL/UNIVERSITY OF ARIZONA

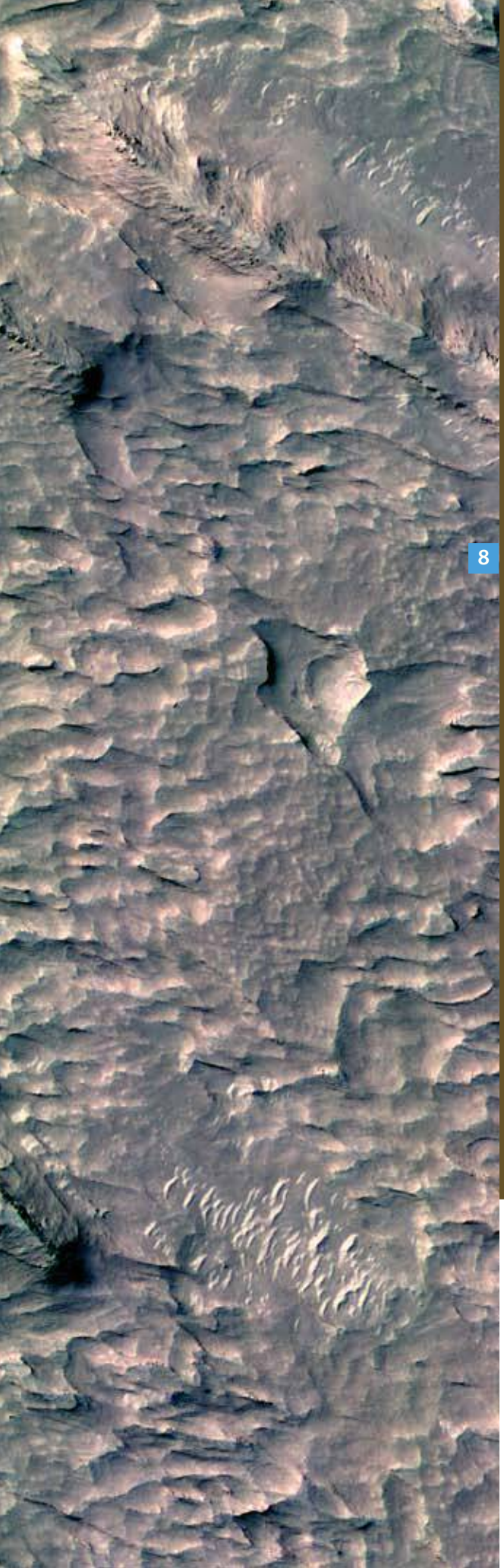
different climates. These plains are flat because the ground ice spreads out and "relaxes" the topography. Impact craters turn into flat circular patterns with more rocks than their surroundings.

HiRISE can see these rocks and the patterned ground (image 3), which results from seasonal processes in the shallow, ice-rich ground. The Phoenix lander, scheduled for launch in August 2007, will touch down somewhere in these vast northern lowlands and dig down to the ice layer to search for carbon-rich materials needed by life-as-we-know-it.

Billions of years ago, water or ice moved through giant channels into the northern lowlands. HiRISE targeted one of these channels, Mawrth Vallis, because the European Mars Express mission recently discovered abundant clay minerals near it. Clays form when water remains available for a long enough period to alter the rocks and soils. And that means a good environment for life to flourish — if it ever existed on Mars.

The HiRISE image (4) shows distinct color and topographic variations that reveal the region's geologic history. After the clays formed, the entire region was buried under hundreds of feet of fine-grained materials like dust or very fine sand. Winds are stripping away this material (which appears orange and blue in the enhanced color image), exposing the bright clays. We know the clays must be billions of years old because many large impact craters dot the region, even in the overlying, younger material.

A few hundred miles east of Mawrth Vallis lies Becquerel Crater (image 10), which contains an impressive stack of layered rocks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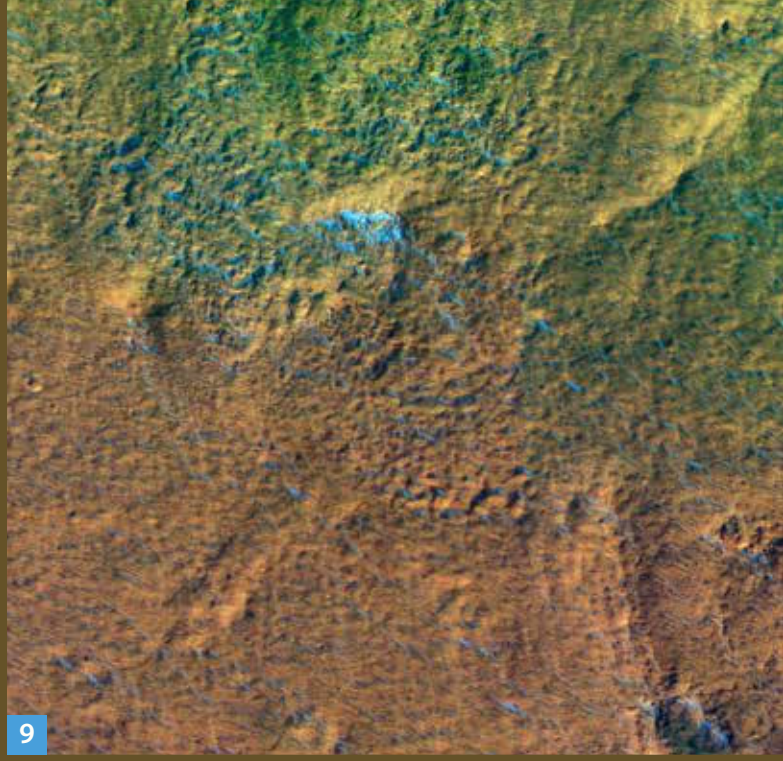
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discovered by the camera on Mars Global Surveyor. HiRISE shows pervasive fractures in the bedrock, which forms angular blocks on slopes. These and other details provide clues to the properties of these deposits and the environment in which they formed, perhaps an ancient lake.

The enormous system of canyons named Valles Marineris spans nearly one-fifth of Mars' equatorial band. HiRISE imaged part of the rugged floor of one of these canyons, named Ius Chasma, September 29 — its first full-resolution image of Mars.

The images (6 and 7) reveal a complex geologic history — with diverse bedrock types showing different colors, layers, and surface

11

12

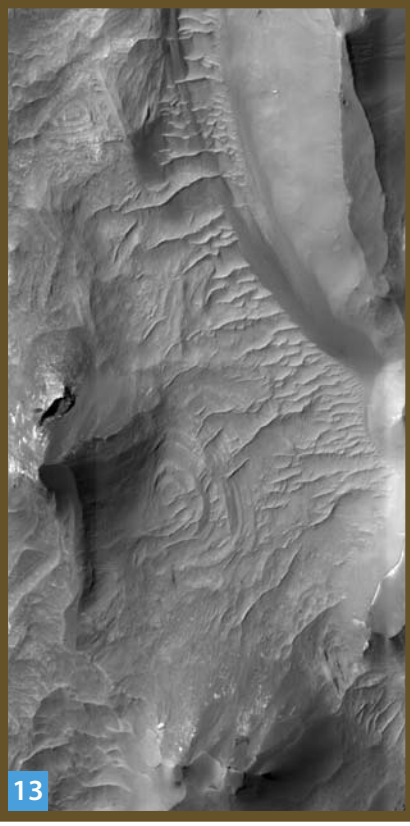
8 THE MEDUSAE FOSSAE FORMATION near Mars' equator features wind-sculpted landforms, including these eroded ridges known as yardangs. This region may consist of hardened volcanic ash or a mix of dust and ice from an earlier climate. This image reveals objects as small as 1.5 feet across (0.5m). NASA/JPL/UNIVERSITY OF ARIZONA

9 OUTFLOW CHANNEL NIGER VALLIS shows few craters because windblown debris has eroded or buried all but the freshest ones. This view shows the floor of Niger Vallis, which starts on the flanks of the volcano Hadriaca Patera and empties into the Hellas basin. Objects 3 feet wide (1m) show up in the image. NASA/JPL/UNIVERSITY OF ARIZONA

10 BECQUEREL CRATER features multiple layers of exposed light-toned rock. In some places, you can see "blue" sand that has collected in low spots or against slopes. The smallest features in this image measure just 1.5 feet across (0.5m). NASA/JPL/UNIVERSITY OF ARIZONA

11&12 A CRATER'S STEEP SLOPE shows frost deposited along the walls of shadowed gullies during the long southern winter. The smallest channels seen in these images span less than 3 feet (1m), and downhill lies toward the bottom. NASA/JPL/UNIVERSITY OF ARIZONA

13&14 MRO'S HiRISE CAMERA resolves objects 10 times smaller than the Mars Orbiter Camera onboard the Mars Global Surveyor spacecraft. These images show the floor of Juventae Chasma as seen by HiRISE (13) and MOC (14). LEFT: NASA/JPL/UNIVERSITY OF ARIZONA; RIGHT: NASA/JPL/MSSS



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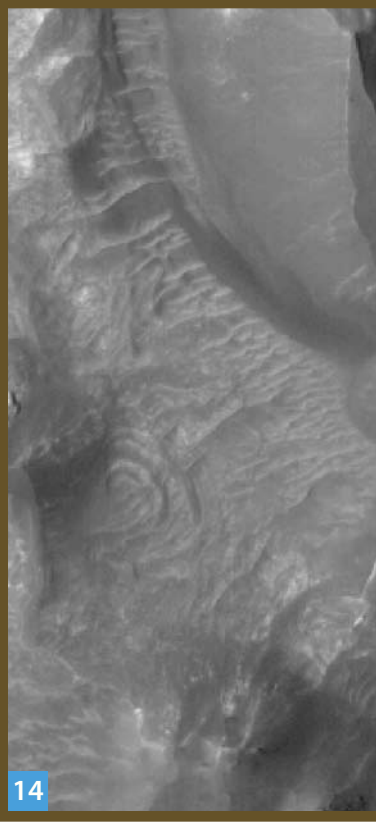

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textures — even in this tiny sample of Ius Chasma. Numerous faults and folds attest to powerful forces in the planet's crust. Valles Marineris is a geologist's wonderland, the martian equivalent of Arizona's Grand Canyon.

The southernmost stop on this brief tour of Mars comes at the gullied slope of a crater in the southern highlands. Such geologically recent gullies excite planetary scientists because they show water can exist as a liquid on Mars' surface even today, at least for brief periods. In the two HiRISE image close-ups (11 and 12), winter still grips the martian southern hemisphere, and the Sun has just started hitting the south-facing slopes in early morning and late afternoon.

The gullies remain almost entirely in shadow, but seasonal frost still covers large areas, which creates a striking color contrast with the reddish dust. The frost could have formed from both carbon dioxide and water vapor in the thin atmosphere. It took many gully-forming episodes to produce this tortured landscape. But if you think this region looks complex, just wait until you see the full-resolution gully images we'll be taking shortly.

These first images provide just a glimpse of what HiRISE will deliver. The camera should return 10,000 images each martian year (nearly 2 Earth years), building up a vast treasure trove of beautiful images. Stay tuned for what promises to be an amazing ride.

What makes Mira tick?

Changes in this star's complex atmosphere power its pulsations. ///

BY ROBERT ZIMMERMAN

"Before we get to today's local forecast, let's take a look at the weather in some other locations across the galaxy. Based on trends over the past several hundred years, those living in the vicinity of the star Mira — also known as Omicron Ceti — can expect to see clearing skies and increasing temperatures during the next couple of months.

"These conditions will peak in March 2007, followed by 6 months of increasing cloudiness and hazy conditions, with sustained winds blowing at a few thousand miles per hour."

What makes this make-believe weather report for Mira different from a typical report on Earth? The Mira forecast is certain to be correct. While meteorologists on Earth have a hard time making accurate predictions even a week ahead, astronomers have started to understand the strange star Mira and its family of compatriots.

What they have found has been unexpected and truly strange: Mira-type stars' most distinguishing feature is their weather!

Supersize it

Until Mira's discovery, the fixed stars were considered permanent and unchanging. True, on rare occasions, observers would see one explode — glowing brightly for weeks or months before fading away — but astronomers assumed most stars shone steadily.

That started to change in 1596. On August 3, Dutch clergyman and amateur astronomer David Fabricius (1564–1617) used a 3rd-magnitude star in the constellation Cetus to pinpoint the planet Mercury's position. Over the next few weeks, he

MIRA'S BLOATED ATMOSPHERE appears reddish because it is cool. Mira's fierce stellar wind gets pulled toward a white-dwarf companion, creating a gaseous bridge that spirals into an accretion disk. NASA/CXC/M. WEISS

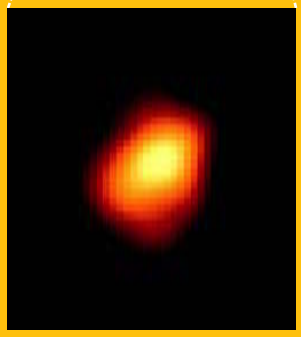
watched the star brighten to 2nd magnitude, then saw it fade slowly. It ultimately vanished from sight in October.

At first, Fabricius labeled the star a nova — one of those rare exploding stars — because it had disappeared. However, 12 years later, he saw it again. Not until the 1630s did astronomers deduce the star's 11-month cycle of variability. Because it was then the only star known to vary in brightness, Johannes Hevelius of Danzig dubbed it Mira, which means "wonderful" in Latin. Fabricius would not live to witness the star's acclaim — he was murdered by a peasant he accused of stealing one of his geese.

Slowly, astronomers began noticing more variable stars. Still, 200 years after Fabricius' initial observations, only 11 variables had been discovered. With the advent of photography in the 19th century, the numbers swelled. Today, astronomers have cataloged tens of thousands. Some pulsate quickly, their light output changing significantly in only days, even hours. Others throb irregularly, their schedules unpredictable and inconsistent.

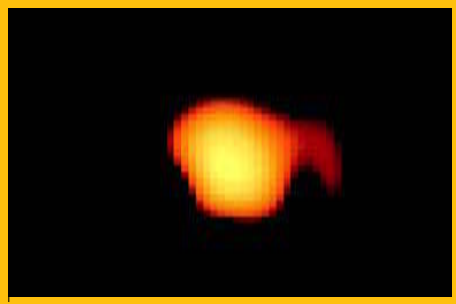
Of the many different types of variable stars, however, by far the most common is what astronomers now call Mira stars, all of which have properties similar to their namesake. Like Mira, these old, M-class red giants have long pulsation periods, taking anywhere from 80 to 1,000 days to dip from maximum to minimum light and rise back. Miras can vary in brightness from two to as many as ten magnitudes — the equivalent of a 10,000 times increase in brightness.

Stellar evolution theory tells us these long-period variable stars foretell the fate of



A COOL RED GIANT, MIRA A (left) appears distinct from its hot companion, Mira B, in this Hubble visible-light image. Less than 1" separates the pair which, at the stars' distance of 420 light-years from Earth, implies a gap of approximately 6.5 billion miles. MARGARITA KAROVSKA (HARVARD-SMITHSONIAN CfA)/NASA

A CLOSE-UP SHOWS Mira A looks a little like a football. The odd shape may result from the star's pulsations or from unresolved bright spots on the surface or in the atmosphere. Hubble measured the red giant's diameter as 700 times that of the Sun. MARGARITA KAROVSKA (HARVARD-SMITHSONIAN CfA)/NASA



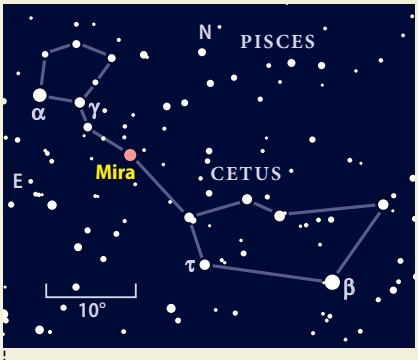
A HOOK-LIKE APPENDAGE extends from Mira A in the direction of its companion in this Hubble ultraviolet image. This could be gas being drawn from the red giant toward its compact neighbor, which lies outside this field of view. MARGARITA KAROVSKA (HARVARD-SMITHSONIAN CfA)/NASA

TRACK DOWN MIRA

This winter provides a superb opportunity to gaze upon the wonderful star Mira. Astronomers expect it to reach maximum brightness during the first half of March, so observers with a dark sky should be able to spot it with naked eyes during January and February. The star will brighten still more by March.

Even better, Mira now stands high in the evening sky. Its host constellation, Cetus the Whale, lies in the southwest and about halfway to the zenith as darkness falls these February evenings. It will appear lower in the west during March, but still high enough to spot easily. Use the circular star map at the center of the magazine to locate Cetus, then zero in on Mira using the finder chart at upper right. You shouldn't have much difficulty spying it from rural or suburban locations, but it will be a challenge to see from the city.

To perceive Mira's color, however, you'll probably need to use some optical aid. Your naked eyes might detect a hint of orange from a dark-sky site, but binoculars or telescopes bring in enough additional light to excite your eyes' color receptors. The color will shift to a deeper red when the star starts to fade after maximum light. At minimum light, you'll need large binoculars or a small scope just to spot Mira, much less to see any shade of red. — *Richard Talcott*



ASTRONOMY: ROEN KELLY

YOU CAN FIND MIRA this winter and spring as it reaches maximum brilliance. The luminous red giant appears conspicuous in central Cetus.

our Sun when it reaches old age. A star possessing between one and two solar-masses spends most of its life burning hydrogen into helium in its core. After several billion years, the core hydrogen is exhausted, and the star swells to a red giant. The core eventually grows hot enough to fuse helium into carbon and oxygen, and the star shrinks in size. Eventually, it depletes its core helium.

Robert Zimmerman *is a frequent contributor to* Astronomy. *Given a chance, he would love to fly a spaceship through Mira's diffuse atmosphere.*

A Mira star represents the next phase of evolution. As the core shrinks for a second time, the star's outer atmosphere expands enormously, swallowing up any inner planets the system might have harbored. At the same time, the star's upper layers and its distended atmosphere become unstable and begin to pulsate. Each pulse throws off enormous amounts of mass, producing a gigantic dust envelope through which any remaining outer planets must travel.

After roughly 10,000 to 50,000 years, such a star will have ejected much of its mass, leaving behind a slowly cooling core that becomes a white dwarf. The white dwarf's intense radiation will light up the previously ejected gas, creating a beautiful planetary nebula.

As archetype of its class and one of the closest at 420 light-years away, Mira's properties are somewhat typical, if breathtaking in scale. In visible light, it typically starts around 9th magnitude at its dimmest and brightens to 2nd magnitude at its brightest, a thousand times increase in luminosity.

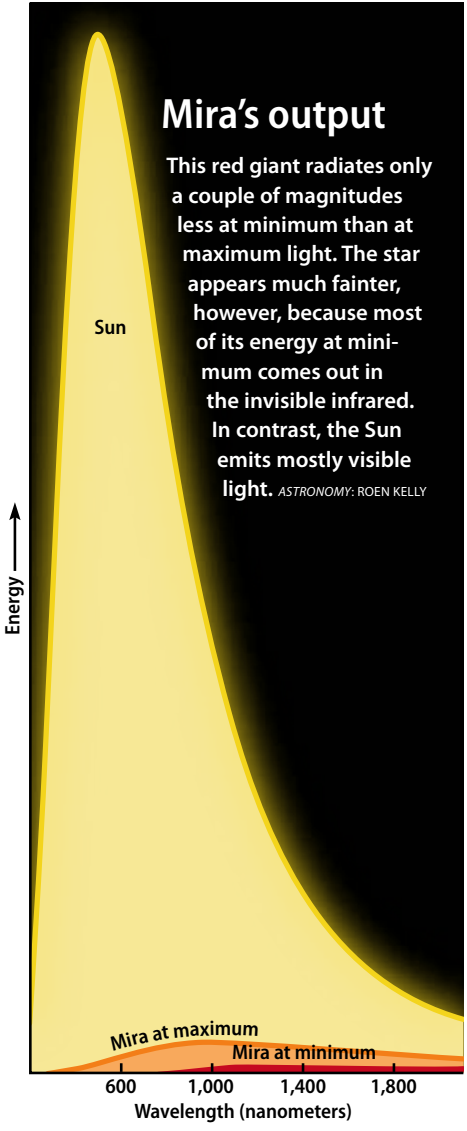
Astronomers have measured these changes for more than a century, and — like most Mira stars — the pulses fluctuate. During its last four cycles, for example, Mira barely has reached 3rd magnitude at maximum. In the past, its maximum has been as dim as 5th magnitude and as bright as 1st magnitude, while its minimum has ranged from 8th to 10th magnitude.

The star's pulsation period averages 332 days, but this also fluctuates. It sometimes completes a cycle in as little as 310 days or as long as 370 days.

As expected for a red-giant star, Mira is huge. Observations at some wavelengths show its radius as big as 2 astronomical units (AU; 1 AU is the average Earth-Sun distance). If Mira were to replace our Sun, its outer reaches would extend beyond the orbit of Mars, consuming all the inner planets as well as much of the asteroid belt. And don't forget, with each pulse, the star can swell an additional 20 percent or more.

Nor is that all. An outer envelope of dust surrounds Mira's bloated atmosphere and extends as far as 100 AU.

Astronomers have a difficult time even defining a Mira star's size. These gargantuan


Mira's output
This red giant radiates only a couple of magnitudes less at minimum than at maximum light. The star appears much fainter, however, because most of its energy at minimum comes out in the invisible infrared. In contrast, the Sun emits mostly visible light. ASTRONOMY: ROEN KELLY
Sun
Energy
Mira at maximum
Mira at minimum
600
1,000
1,400
1,800
Wavelength (nanometers)

AT MAXIMUM LIGHT, Mira (arrow) typically shines around 3rd magnitude and sports a distinct orange hue when viewed through a telescope. RONALD ROYER

gasbags have masses similar to the Sun spread throughout a volume some 100 million times larger. Unlike the Sun, which holds its upper atmospheric layers tightly, forming what appears to be an unambiguous surface, Mira's humongous atmosphere is so diffuse its boundary is indistinct. "The problem with Mira stars is it's hard to draw a distinction between the atmospheres and the stars," explains Mark Reid of the Smithsonian Astrophysical Observatory. "The density of material in the star falls off very slowly as you go outward."

In fact, the material in a Mira star's swollen atmosphere spreads out so much in its outer reaches that if you flew a spacecraft through it, it would pass for a good laboratory vacuum.

Mira ranks among the coolest stars known. Its lukewarm upper atmosphere ranges from about 1,500 to 2,800 Kelvin during each cycle — roughly one-fourth to one-half the Sun's surface temperature. Mira gets its deep reddish color from this tepid temperature. Essentially, all Mira stars act like giant heaters, radiating most of their energy on the red end of the spectrum.

Despite their amazing fluctuations in visible light, Mira stars don't vary nearly as much across the entire electromagnetic spectrum. In the 1930s, astronomers realized the large changes are confined mostly to optical wavelengths. Total luminosity rises and falls an average of only two magnitudes over each star's long cycle. At minimum light, a Mira star's surface is coolest. Most of the star's radiation lies in the infrared part of the spectrum, which the human eye can't see. At maximum light, the hotter surface has its energy peak closer to visible wavelengths, so we see a much-larger proportion of the star's radiation.

Forecast: cloudy and windy

Scientists have also come to realize these gigantic, pulsating stars don't balloon and deflate as much as was earlier thought. Past estimates of size changes sometimes confused the opaque top layer of such a star's atmosphere with its surface. Although Mira stars' diameters may fluctuate by as much as 40 percent during their cycles, most of the largest size changes astronomers measure actually represent changes in the opacity of the stars' atmospheres.

Mira's puffed-up atmosphere is a messy place. Astronomers have detected a plethora of elements there, including hydrogen, oxygen, carbon, silicon, and titanium. These elements are usually combined in a variety of molecules such as water, sulfur dioxide, carbon dioxide, silicon oxide, and many other metal oxides. In infrared images, Mira's outer dust envelope appears as numerous interlaced and overlapping arcs and rings, mere fragments that only partially surround the star. Research suggests recurring changes in this complex atmosphere drive the apparently huge brightness swings seen in visible light.

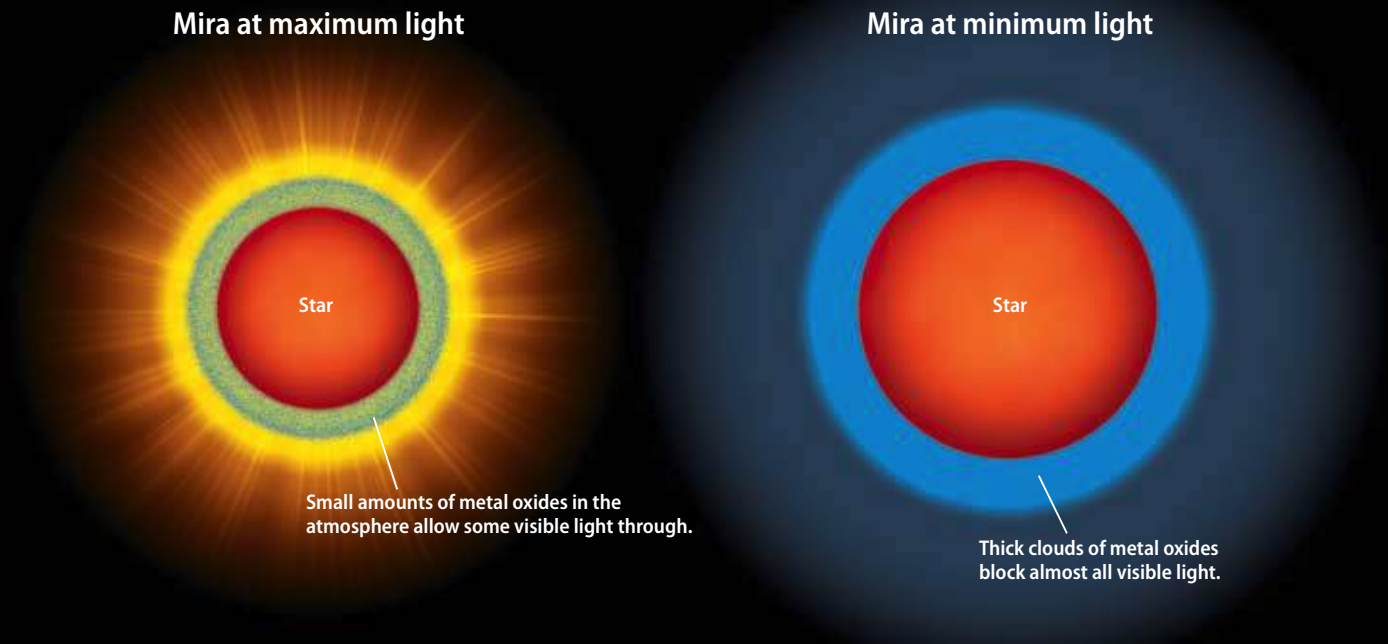
Like Earth's atmosphere, Mira's tenuous atmosphere transports energy by convection. Its main weather pattern, however, is the approximately 332-day-long heating-and-cooling cycle caused by pulsations and instabilities rising up from within the star.

At maximum light, the star is smallest and hottest. The heat ionizes hydrogen just beneath the star's surface, breaking the atoms apart into individual protons and electrons. This is what allows the star's light to escape.

As the light escapes, however, it interacts strongly with the electrons, pushing them outward and causing the star to expand and cool. When the subsurface temperature drops below 3,000 Kelvin, the protons and electrons recombine into atoms. They fall inward, making the star once again shrink and grow warmer, repeating the cycle.

During this process, the star's atmosphere also pulsates, driven by the same stellar heating-and-cooling cycle. "The atmosphere itself swells and comes back, then swells and comes back again," notes Margarita Karovska of the Harvard-Smithsonian Center for Astrophysics.

What happens when Mira varies?


Mira at maximum light
Star
Small amounts of metal oxides in the atmosphere allow some visible light through.
Mira at minimum light
Star
Thick clouds of metal oxides block almost all visible light.

MIRA CHANGES VISUALLY from maximum light (left) to minimum (right). The star (shown in red) is smaller and hotter at maximum. Its extended atmosphere (yellow) allows some visible light through, so observers on Earth can see close to the stellar surface. Near minimum light, Mira's temperature drops so much that metal oxides (blue), most notably titanium oxide, condense in the star's tenuous outer atmosphere, blocking visible light and radiating strongly in the infrared. *ASTRONOMY:* ROEN KELLY, AFTER M. REID (SAO) AND J. GOLDSTON (UC, BERKELEY)

At the low-temperature phase during minimum light, the atmosphere can cool to as low as 1,500 Kelvin. According to Reid and his colleague, Josh Goldston of the University of California, Berkeley, at that temperature, oxygen and titanium atoms in the atmosphere naturally combine to form molecules of titanium oxide — the main ingredient in many sunscreens.

In other words, the star's light dims so dramatically because dark clouds of sunscreen form in its outer atmosphere, blocking the star's light.

Because the star itself has not grown any less luminous, its radiation continues to heat the atmosphere. Held in by these clouds, the mounting heat eventually breaks apart the titanium-oxide molecules and the atmosphere clears, once again unveiling the bright star underneath.

Each pulsation cycle isn't zero sum. During the expansion wave, some material reaches the outer parts of the star's atmosphere and condenses into dust grains. This dust does not fall back into the star. Instead, radiation pressure pushes it outward, forming a wind of dust that fans out at upward of 22,000 mph (36,000 km/h).

Over several tens of thousands of years, exceptionally strong pulsations ultimately puff off a Mira star's outer layers. These expanding gas shells eventually form a planetary nebula, with the star's corpse — a white dwarf — at the center. In this way, Mira variables provide most of the dust that exists in the universe.

Mira's peculiarities

Mira's case is complicated even more because the star belongs to a binary system. The companion, discovered by Alfred Joy with the 100-inch telescope at Mount Wilson Observatory in the early 1920s, is a white dwarf located approximately 70 AU from Mira. Because the companion — dubbed Mira B — travels a long, slow course around the giant star, its orbit has yet to be charted precisely. Since astronomers first photographed it in the 1920s, the white dwarf's separation from Mira has been shrinking slowly, from 0.9" in 1923 to 0.6" now. Observations convince some astronomers that the companion star also varies, fluctuating by a couple of magnitudes every 14 years.

Using the space-based and improved ground-based telescopes available since the 1990s, astronomers have gotten a much clearer look at this binary. In 1995, a team led by Karovska took the first Hubble pictures of the Mira system and discovered significant asymmetries in the giant star's atmosphere. Although they ascribe some of this distortion to "unresolved bright spots on the surface of the star or in [its] atmosphere," the first ultraviolet image shows a distinct hook-like appendage warped in the direction of the companion star. This suggests the companion's gravity pulls Mira's atmosphere out of whack.

Astronomers weren't shocked by this discovery. As Mira's powerful wind of gas and dust blows outward, the companion's gravity draws it in. The material spirals toward the white dwarf, forming an accretion disk. The wind's collision with this disk produces the energy fluxes these scientists detected using Hubble.

In 1999, however, Karovska, Brian Wood of the University of Colorado, Boulder, and Warren Hack of the Space Telescope Science Institute discovered the system's ultraviolet output had dropped by 95 percent since it was first measured by the International Ultraviolet Explorer satellite in the 1980s. Somehow, in the ensuing decade, the flux from this wind/disk collision had fallen dramatically. The scientists suggested something happened to reduce the accretion rate onto the companion.

The same team of astronomers used the orbiting Far Ultraviolet Spectroscopic Explorer to observe Mira in 2001. The scientists confirmed the low emission and proposed the accretion falloff was related somehow to the companion star's 14-year period of variability.

In fact, the data suggest Mira B might not fluctuate. Instead, Mira A might have an additional 14-year cycle during which the wind's intensity changes. At maximum, the accretion disk surrounding the companion brightens under the intensified wind's onslaught. At minimum, the disk dims as lighter wind hits it. Recent Hubble observations support this theory — the flux from the accretion disk once again appears to be rising, returning to its older value and in synch with the 14-year cycle.

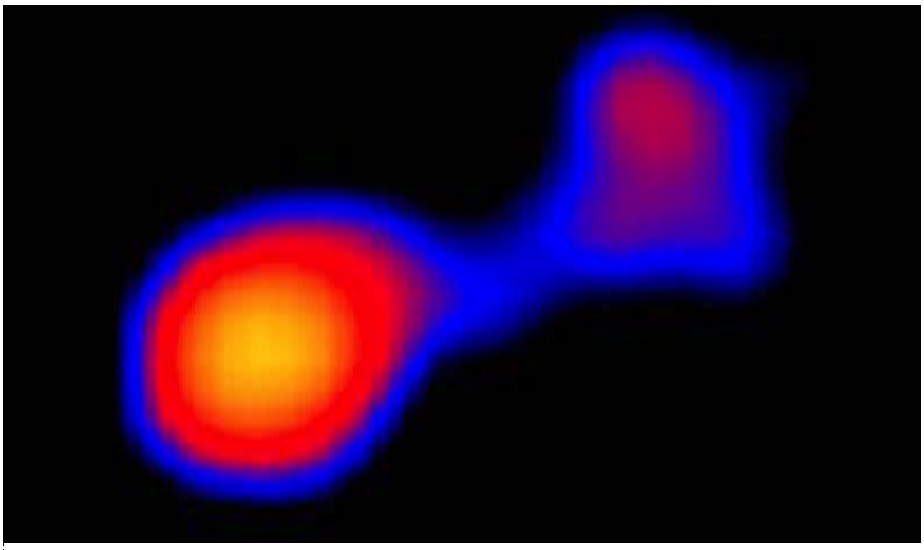
Why Mira should have a secondary 14-year period remains a mystery. One suggestion proposes an undetected third star exists in the system. Another, more exotic hypothesis, speculates that Mira's shape throbs asymmetrically every 14 years, with one hemisphere becoming squashed while the other swells.

Karovska, Wood, and Hack observed Mira again in 2003, this time with the Chandra X-ray Telescope, and found something even more surprising. The scientists expected to see X rays coming only from the accretion disk. As Karovska noted, "Single Miras do not emit X rays." To their bewilderment, not only was Mira A giving off X rays, it also produced an X-ray flare while they were observing. "We couldn't believe it!" says Karovska of the first such outburst ever detected from a Mira star.

THE FATE OF MIRA — and of all stars with roughly the Sun's mass — is as a planetary nebula like the Eskimo seen here. Repeated pulsations eventually puff off these stars' outer layers, and the gas glows as ultraviolet radiation from the hot white dwarf left behind excites it. NASA/A. FRUCHTER/THE ERO TEAM (S. BAGGETT [STScI], R. HOOK [ST-ECF], AND Z. LEVAY [STScI])

The team theorizes a magnetic flare on the star's surface, followed by a large mass ejection similar to coronal mass ejections seen on the Sun, could have caused this outburst. If so, as this material expands and cools, dust formation should increase in the outer parts of the star's atmosphere.

The Chandra X-ray data also show an X-ray "bridge" extending between the primary and secondary stars. This is more evidence that Mira B distorts Mira A's atmosphere and pulls a stream of material toward it. This occurs despite a separation of 6.5 billion miles (10 billion km) — or twice the distance between the Sun and Pluto.



X-RAY OBSERVATIONS of Mira show both the primary star (right) and secondary, with a gaseous bridge between the two. Bright X rays arise both from a massive flare on Mira A and from particles colliding rapidly in Mira B's accretion disk. NASA/CXC/SAO/M. KAROVSKA ET AL.

Going sightseeing

Although no telescope yet has the resolution to photograph the atmosphere of any Mira star, observations and theory suggest that when astronomers finally do so, they will witness a planetary nebula in its birth throes.

At Mira, we likely will see a complex, interwoven series of gaseous shells flowing in and out as the star's atmosphere moves through its 11-month pulsation period. As Mira cycles from bright to dim, the inner core probably will disappear, obscured by thick clouds forming in the cooling atmosphere.

At its dimmest, the star will be replaced by a glowing overcast of thick haze. Then, slowly, the fog will lift and the star will peek out again, and the cycle will begin anew.

Meanwhile, the weather here on Earth will remain unpredictable.

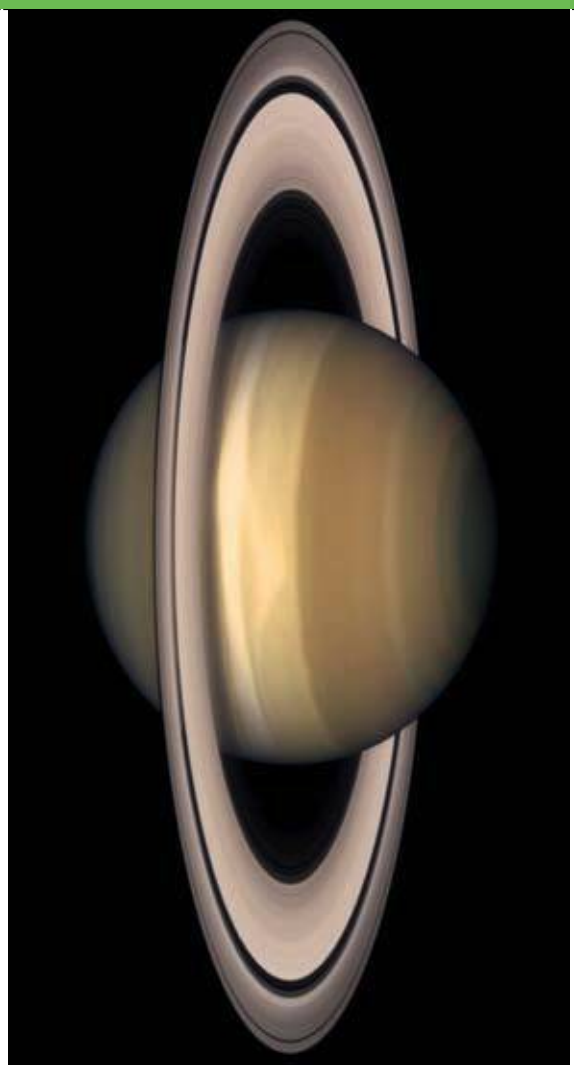
BY MARTIN RATCLIFFE AND ALISTER LING

FEBRUARY 07

The ringed planet dazzles

Two planets put on great shows

this month. While Mercury climbs into view in the early evening, beautiful Saturn remains visible all night. The evening sky also offers asteroid Iris near the Pleiades star cluster and an 11th-magnitude comet, P/2001 Q2 (Petriew). February mornings introduce Jupiter and Mars, along with a promise of better views later this year.

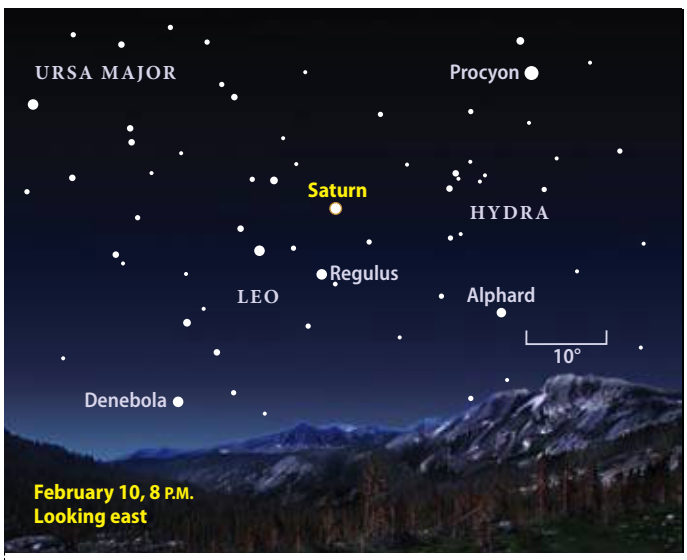


NASA/THE HUBBLE HERITAGE TEAM (STScI/AURA)

SATURN'S GLORIOUS RINGS stand out through even the smallest telescope. The dark gap, known as the Cassini Division, that separates the outer A ring from the brighter B ring shows up best well away from Saturn's globe. The slim Encke Division near the A ring's outer edge appears only with the best seeing.

48 Saturn at its best
53 Delta Leonid meteors
53 Lunar crater Bürg
54 Mercury shines brightly
54 Asteroid 7 Iris
55 Saturn and its moons
55 Comet P/2001 Q2

Visible to the naked eye
Visible with binoculars
Visible with a telescope



SATURN'S GLOW appears conspicuous in the eastern sky after darkness falls this month. The ringed planet remains visible all night as it reaches the peak of its 2007 apparition. *ASTRONOMY*: THEO COBB

Evening planets

Mercury hugs the western horizon after sundown in early February. The innermost planet came into view at January's close, and it continues to climb higher during February's first week. On the 1st, it shines brightly at magnitude –0.9.

On February 7, Mercury reaches greatest elongation, when it lies 18° east of the Sun and appears highest after sunset. The easiest way to find the planet is to look 7° to the lower right of the much brighter planet Venus.

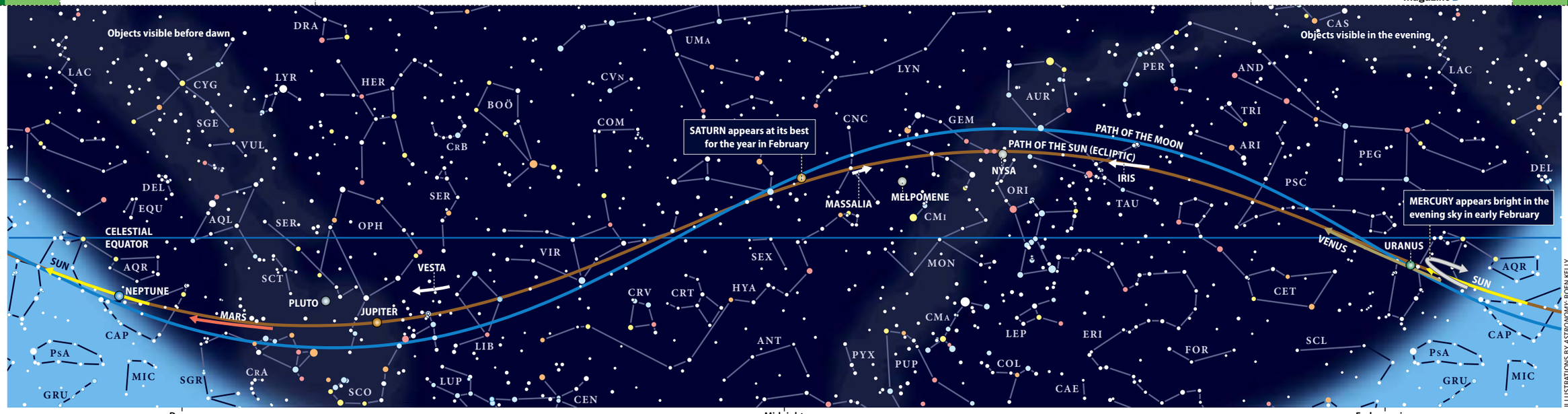
During February's first week, Mercury's telescopic

— *continued on page 53*

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.

Astronomy magazine



ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

[19] [18] [17] [16] [15] [14] [13] [12] [11] [10] [09] [08] [07] [06] [05] [04] [03] [02] [01]

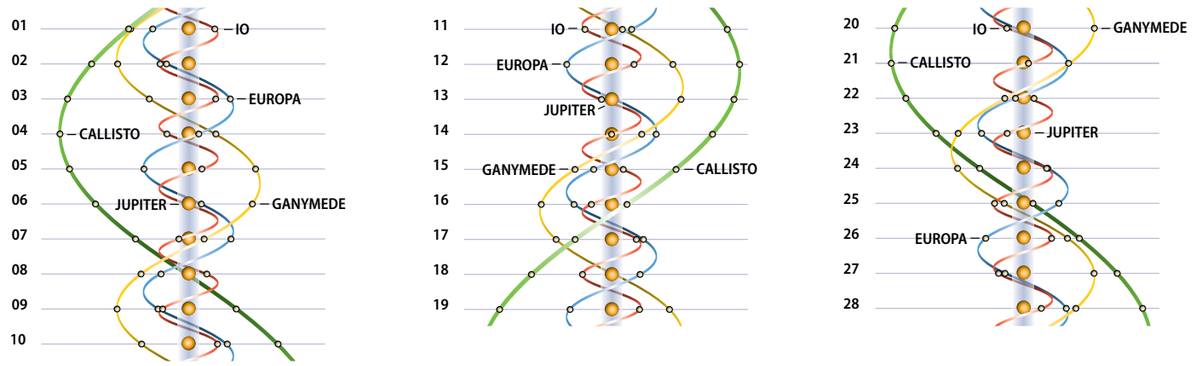
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

[28] [27] [26] [25] [24] [23] [22] [21] [20] [19] [18] [17] [16]

PLANETS	MERCURY	MERCURY	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	February 1	February 15	February 15	February 15	February 15	February 15	February 15	February 15	February 15
Magnitude	–0.9	1.1	–3.9	1.3	–2.0	0.0	5.9	8.0	14.0
Angular size	6.0"	8.9"	11.4"	4.3"	35.1"	20.3"	3.4"	2.2"	0.1"
Illumination	78%	19%	90%	96%	99%	100%	100%	100%	100%
Distance (AU) from Earth	1.130	0.760	1.463	2.163	5.613	8.203	21.027	31.031	31.757
Distance (AU) from Sun	0.330	0.316	0.724	1.457	5.353	9.188	20.088	30.049	31.242
Right ascension (2000.0)	22h01.1m	22h42.6m	23h32.8m	19h33.7m	16h59.6m	9h36.1m	23h00.4m	21h28.5m	17h53.1m
Declination (2000.0)	–13°02'	–5°26'	–4°17'	–22°30'	–22°00'	15°41'	–7°09'	–15°09'	–16°32'

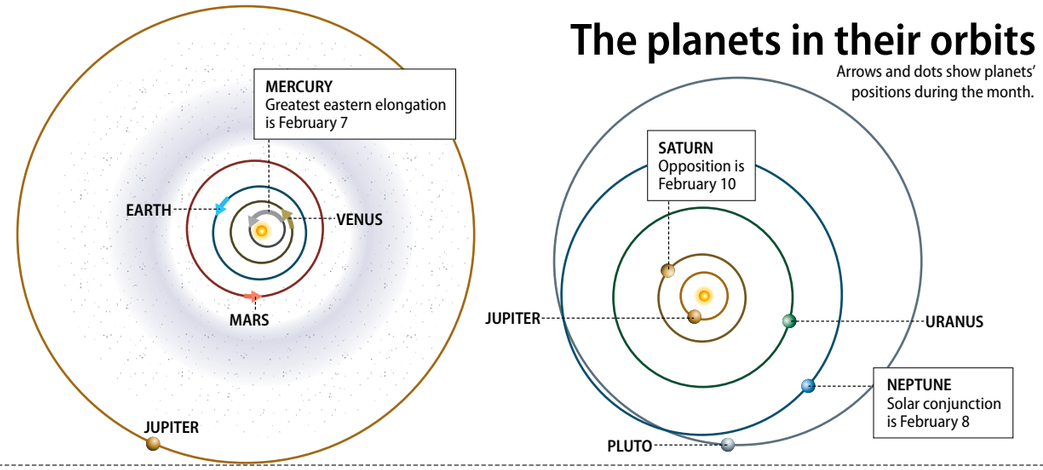
Jupiter's moons

Dots display positions of Galilean satellites at 6 A.M. EST on date shown. South is at top to match the view through a telescope.



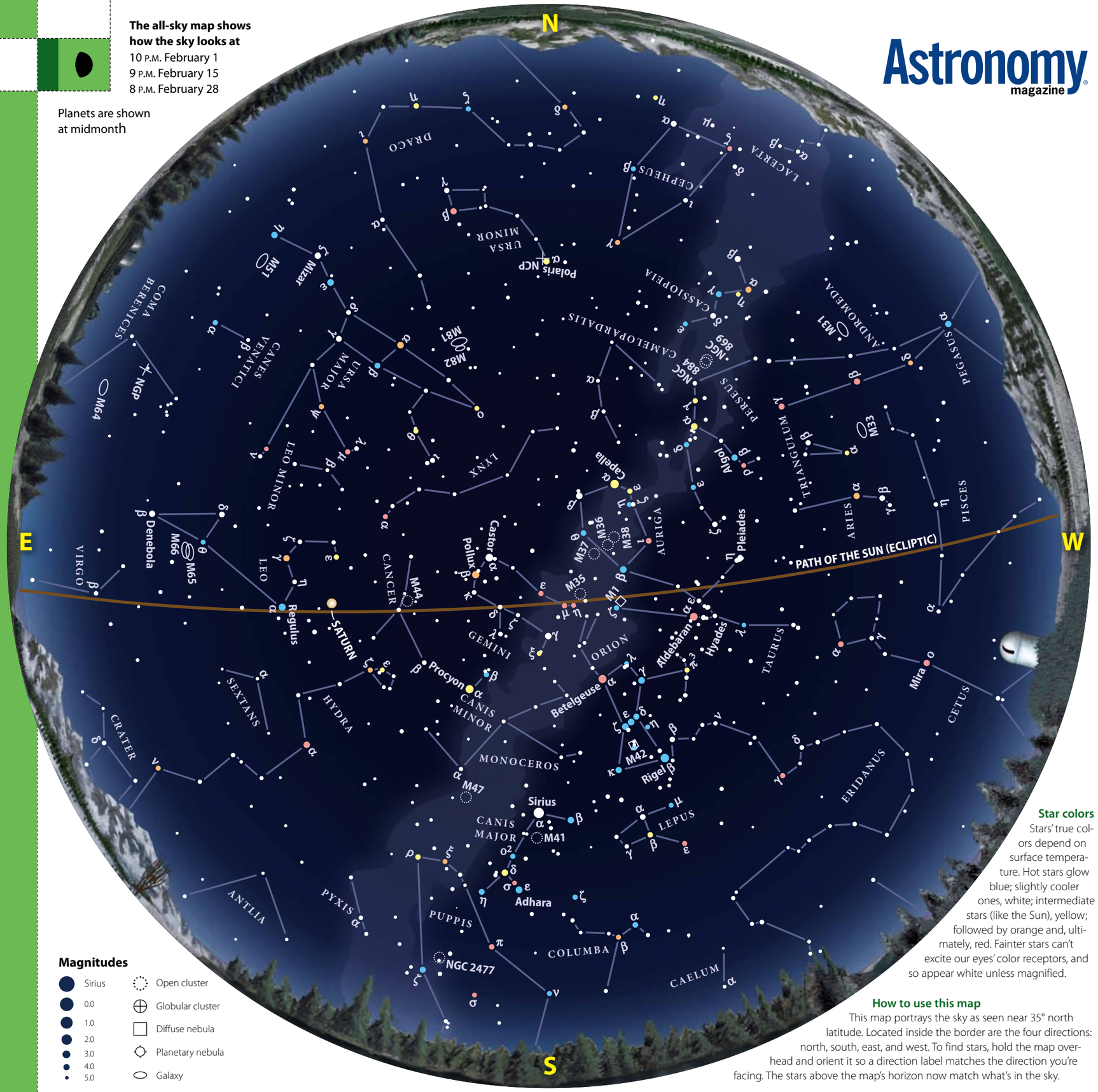
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
10 P.M. February 1
9 P.M. February 15
8 P.M. February 28

Planets are shown at midmonth



Magnitudes

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0
- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

Star colors
Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

How to use this map
This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Astronomy magazine

february 07

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
				[01]	[02]	[03]
[04]	[05]	[06]	[07]	[08]	[09]	[10]
[11]	[12]	[13]	[14]	[15]	[16]	[17]
[18]	[19]	[20]	[21]	[22]	[23]	[24]
[25]	[26]	[27]	[28]			

01 Asteroid Pallas is in conjunction with the Sun, 5 P.M. EST

02 Full Moon occurs at 12:45 A.M. EST

The Moon passes 0.9° north of Saturn, 6 P.M. EST

03 The Moon passes 1.1° north of Regulus, 9 A.M. EST

07 The Moon is at apogee (251,651 miles from Earth), 7:38 A.M. EST

Venus passes 0.7° south of Uranus, 8 A.M. EST

Mercury is at greatest eastern elongation (18°), noon EST

The Moon passes 1.3° south of Spica, 11 P.M. EST

08 Neptune is in conjunction with the Sun, 11 A.M. EST

10 Last Quarter Moon occurs at 4:51 A.M. EST

Saturn is at opposition, 2 P.M. EST

11 The Moon passes 0.7° south of Antares, 5 P.M. EST

12 The Moon passes 6° south of Jupiter, 5 A.M. EST

14 The Moon passes 4° south of Mars, 8 P.M. EST

17 New Moon occurs at 11:14 A.M. EST

19 The Moon is at perigee (224,586 miles from Earth), 4:36 A.M. EST

The Moon passes 2° north of Venus, noon EST

22 Mercury is in inferior conjunction, midnight EST

24 First Quarter Moon occurs at 2:56 A.M. EST

ONLINE EXTRA For definitions of terms, visit www.astronomy.com/glossary.

— *continued from page 48*

appearance changes noticeably. Although its apparent diameter grows by just 1", its phase shrinks from 78-percent- to 56-percent-lit. By the 14th, Mercury's orbit has carried it closer to the Sun, and the planet then lies much closer to the horizon. Its glow has faded to magnitude 0.8, while its phase has waned to a crescent. Soon thereafter, Mercury disappears into the bright evening twilight. Mercury passes between the Sun and Earth February 22/23, prelude to a poor morning apparition in March.

The dramatic glow of **Venus** dominates the western sky after sunset. Shining at magnitude –3.9, it's easy to spot just half an hour after sunset. By 7 P.M. local time, the sky will be dark, and with transparent skies, you may see some of the background stars of Aquarius. On February 6, Venus lies 1° southeast of the 3.7-magnitude star Lambda (λ) Aquarii. Binoculars will give the best view of this conjunction. Observers with a clear western horizon will have the greatest chances of seeing the star.

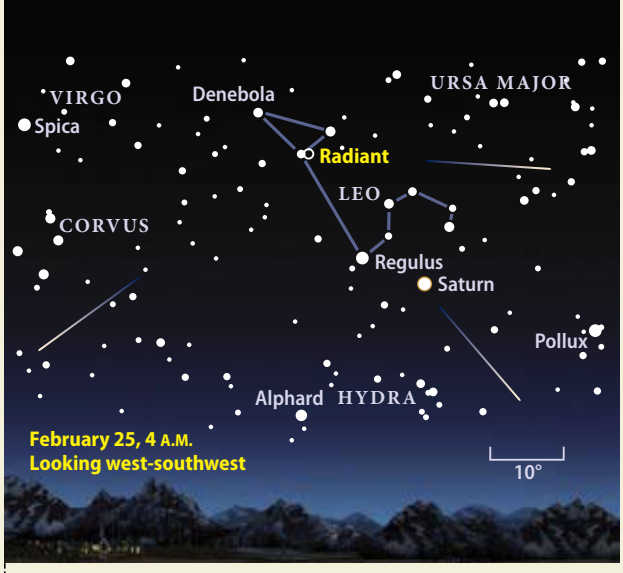
Also take a look for nearby **Uranus** that night. The distant planet glows at magnitude 5.9, and only the most transparent skies will reveal it. Try to find it again the following evening, when Venus and Uranus pass their closest. The two planets then lie just 0.7° apart and stand 5° above the horizon at 7 P.M. local time.

A telescope shows Venus looking similar to how it did last month. A gibbous phase of 92-percent-lit February 1 wanes slowly to 87-percent-lit 4 weeks later. This change results from Venus' orbital motion relative to Earth's. The two planets won't line up on the same side of the Sun until August. In the intervening months, Venus' phase will shrink with increasing rapidity.

A corresponding increase in the planet's size will accompany these changes. At the start of February, Venus' disk spans a diminutive 11", and it grows just 1" by month's end. By June, Venus will have doubled in size because the distance between our two planets will be halved. In mid-February, Venus lies about 135 million miles from Earth. It will come within 25 million miles in August.

The naked-eye view of Venus in the darkening twilight always grows more attractive with the presence of a crescent Moon. On February 19, the

Martin Ratcliffe *is the former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*



ASTRONOMY: THEO COBB

THE DELTA LEONID METEOR SHOWER peaks February 25, although the rate reaches only around 2 meteors per hour.

A SPARSE MONTH FOR METEORS

February doesn't rank high on meteor observers' radar. Sporadic rates are at their lowest of the year, and the month's two minor showers don't do much to compensate. The Alpha Centaurid meteor shower peaks February 8, but it can be seen only from the Southern Hemisphere.

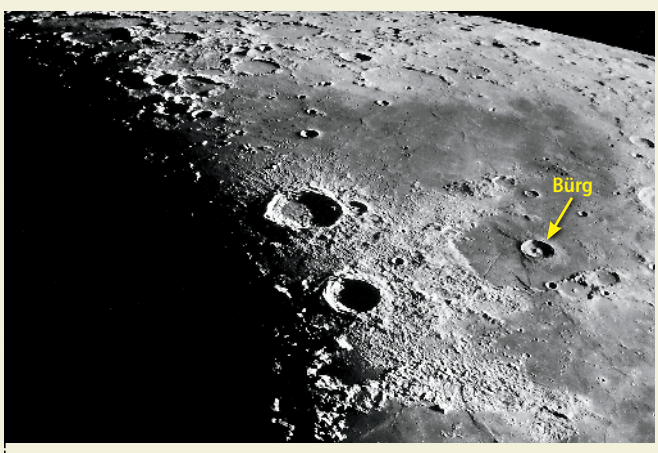
The Delta Leonid shower peaks February 25, when dedicated observers may see one or two meteors per hour originating near the star Delta (δ) Leonis. At least the Moon shouldn't interfere much — the waxing gibbous Moon sets before 3 A.M.

Delta Leonid meteors travel relatively slowly, and they typically appear faint. To confirm a meteor's identity, chart the meteor's path and see if it points back to the radiant. Astronomers think this shower originates from debris released by the asteroid 4450 Pan.

A LUNAR YOUNGSTER

Bürg Crater lies near the center of a small patch of mare called Lacus Mortis, Latin for Lake of Death. This classic young impact crater measures 25 miles across and lies midway between the larger craters Eudoxus and Hercules. You can find this area northeast of Mare Serenitatis.

Bürg has obvious terraced walls, with a floor just over a mile deep, and a central mountain peak. At low solar illumination, just after the Sun rises over the region or just before the Sun sets, two distinct ejecta areas show up on Lacus Mortis' floor, one southwest and the other northwest of Bürg. Both ejecta blankets have distinct western edges.



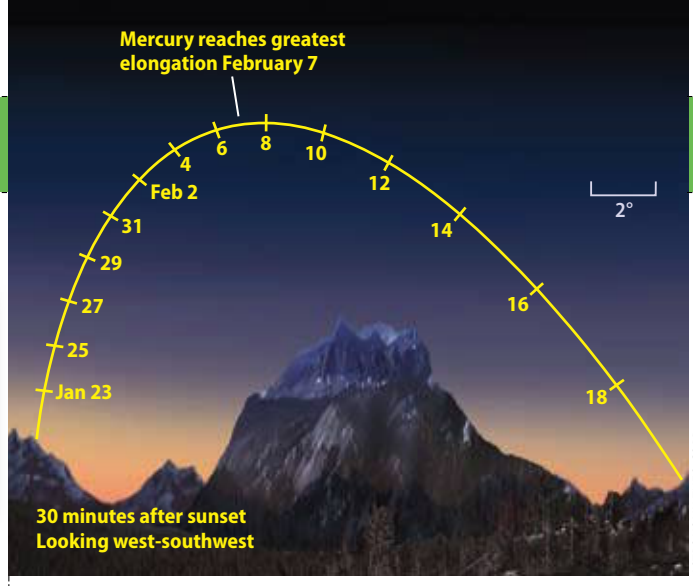
FROM *CONSOLIDATED LUNAR ATLAS* (UA/LPL)

THE LUNAR CRATER BÜRG has terraced walls and a prominent central peak. You can find it northeast of Mare Serenitatis.

Between these ejecta blankets lie two rilles called Rimae Bürg that meet and form a T shape. Under excellent seeing, you might be able to see a tiny pair of craters near the T's junction. During February, you can catch sunrise over this region February 22; sunset occurs February 7.

/// WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Mercury (west)	Saturn (south)	Mars (southeast)
Venus (west)		Jupiter (southeast)
Saturn (east)		Saturn (west)
Uranus (west)		



ASTRONOMY: THEO COBB

MERCURY'S EXCELLENT EVENING APPARITION peaks around its February 7 greatest elongation. On that evening, you can find the innermost planet 11° high half an hour after sunset.

"smiley face" of the slender Moon hangs 5° above Venus.

At the midnight hour

Magnificent **Saturn** appears at its best for the year during February. Opposition occurs February 10, when the planet lies opposite the Sun in our sky and, consequently, rises as the Sun sets. The ringed planet remains on view all night, with the best views coming near local midnight, when it approaches within 30° of the zenith for observers at mid-northern latitudes.

Throughout February, Saturn shines at magnitude 0.0, its brightest for the year. Look 8° to the planet's southeast, and your eyes will fall on blue-white Regulus, Leo the Lion's brightest star. Saturn outshines 1st-magnitude Regulus by 3 times.

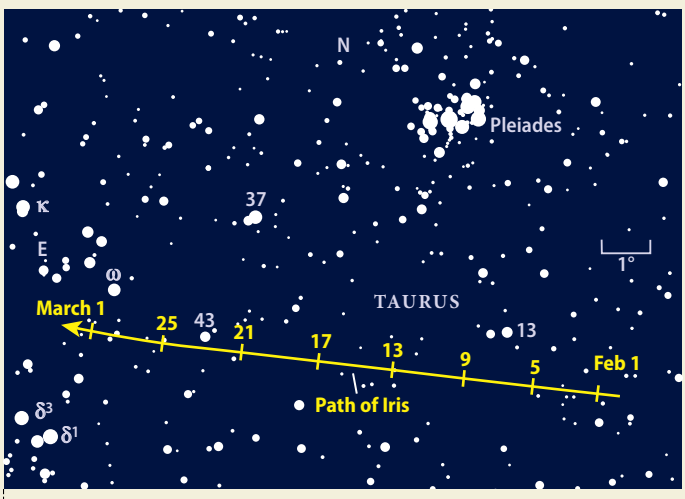
At opposition, Saturn lies closest to Earth, just 762 million miles away. This relative proximity delivers the best views of the planet. Through a telescope, Saturn's most obvious feature is its spectacular ring system. Small scopes reveal the three principal rings: A, B, and C. The outer A ring appears slightly dimmer than the adjacent B ring. A dark gap known as the Cassini Division separates these two rings. The inner C ring shows up through 6-inch or larger telescopes on excellent nights. This ring is transparent enough that you can glimpse Saturn's disk through it.

The apparent tilt of the rings has been dropping for a few years now, and they will appear edge-on in 2009. The rings currently span 46" wide and measure 11" tall. The modest tilt provides a better view of the planet's 20.3"-diameter disk. Don't expect to see much detail, however. The relatively dark equatorial belt stands out best.

To see finer belts and zones in Saturn's atmosphere, be patient. Subtle detail usually becomes visible only with continuous viewing over several minutes. A quick, casual glance never reveals such features. It takes a while for the eye to adapt to seeing detail on a bright object surrounded by black sky. Furthermore, Earth's turbulent atmosphere rarely stays steady for long. Brief moments of steadiness — what astronomers call "good seeing" — allow detail to shine through.

Backyard observers also should look for several saturnian moons. The brightest is Titan, which glows at magnitude 8.4. You can find this planet-sized world due north of Saturn February 4 and 20, and due south of the ringed world February 11 and 28.

Most of Saturn's other visible moons orbit closer to the planet



ASTEROID IRIS slides south of the Pleiades this month. The 9th-magnitude space rock will be easy to pick out. ASTRONOMY: THEO COBB

THE FLOWER MEETS THE BULL

Earth has long since passed the main-belt asteroid 7 Iris and is leaving it behind. Yet the space rock still glows decently at magnitude 9.3 this month, although that's 10 times fainter than its 6.8-magnitude peak this past November.

As such, it's outside the range of most binoculars and does a better job of hiding among the multitude of Milky Way stars littering the western flank of Taurus the Bull. Still, its proximity to the Pleiades star cluster (M45) makes it an easy target to track down.

Locating an asteroid with a 4-inch scope from your backyard is straightforward. It takes only a couple of nights if you're not in a rush — and you shouldn't be, because stargazing is supposed to be relaxing.

Use the finder chart to locate Iris' approximate field, then make a quick sketch showing the positions of half a dozen bright stars. Come back a night or two later to see which "star" moved. Avoid the nights of February 21 to 26, when the glare of the nearby Moon will interfere.

HOME IN ON A (RELATIVELY) NEW COMET

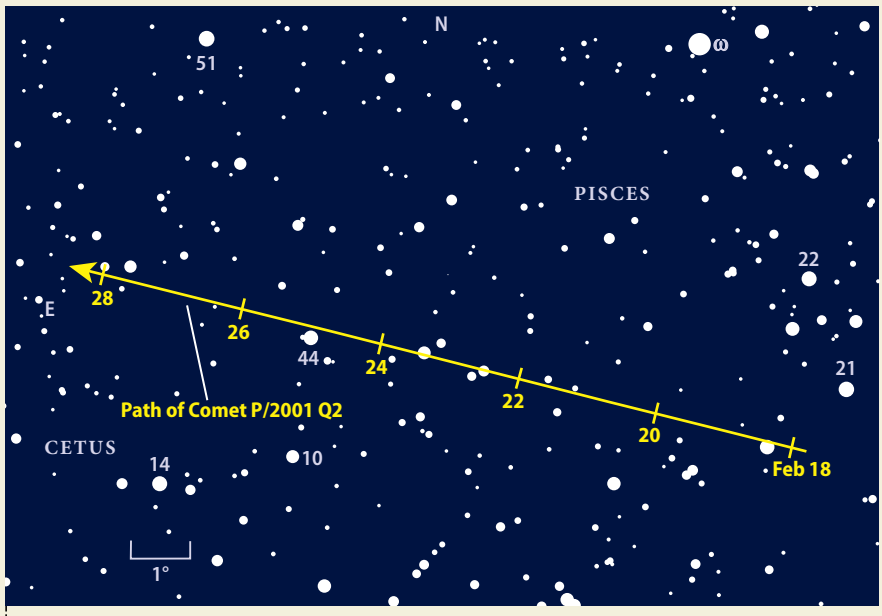
Backyard observers still occasionally discover a comet by chance — although this is increasingly rare because of several ongoing automated searches. A few years ago, at the annual Summer Saskatchewan Star Party, amateur astronomer Vance Petriew was sweeping the sky for the Crab Nebula (M1) just before dawn. Not yet totally comfortable with his new scope, Petriew star-hopped from the wrong star and landed on a soft fuzzball instead of M1.

After carefully sketching its position and getting other experienced observers to confirm it wasn't a known deep-sky object, Petriew raced against the approach of sunrise. He needed a second position to get the unknown object's direction and speed. Without this critical information, it would be tough to recover the comet the next night, and he might not get credit for the discovery. Fortunately, he did get the position, and the comet now bears the name P/2001 Q2 (Petriew).

The comet takes 5.5 years to orbit the Sun out to Jupiter and back. This month, it makes its first return since discovery and should glow around 11th magnitude from its perch above Venus in the west after sunset. Because all objects lose some luster when they lie low in the sky, don't wait long. The comet sets by 8 P.M.

Comet Petriew passes its closest point to the Sun, a bit inside Earth's orbit, February 24. As a result, it moves a little faster than our planet and will climb gradually away from the Sun during the next few months.

During the moonless evenings after February 4, look for the comet near the Pisces Circlet. By month's end, it has brightened slightly and moved into Cetus. It could prove too much of a challenge for a 6-inch scope. Make sure you are dark-adapted, and use averted vision, looking a bit to the side.



COMET P/2001 Q2 (PETRIEW) moves from Pisces into Cetus this month. The 11th-magnitude comet appears low in the west after darkness falls.

than Titan. Near the edge of the rings lies Enceladus, whose watery geysers provide the particles that make up the E ring (invisible to Earth-bound telescopes). Glowing at magnitude 11.8 and located close to the rings' bright glare, Enceladus presents a challenge for most backyard scopes. Three brighter moons lie farther from the rings: Tethys (magnitude 10.3), Dione (10.4), and Rhea (9.7).

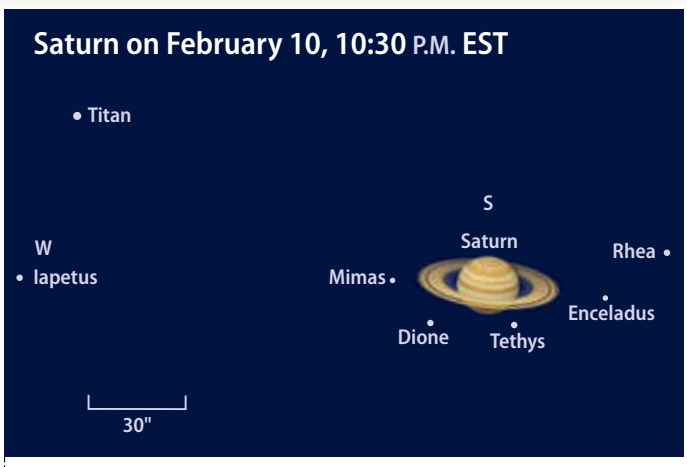
One moon visible through amateur scopes lies outside Titan's orbit. Iapetus passes due south of Saturn the night of February 13/14. This 11th-magnitude moon dims during February, so try to spot it no later than midmonth.

Morning planets

As Saturn starts to dip in the west, **Jupiter** rises in the southeast. Shining brilliantly at magnitude –2.0, the giant planet can't be mistaken for any other celestial object.

Jupiter's yellowish hue contrasts nicely with the ruddy glow of nearby Antares, the brightest star in Scorpius. Antares lies 8° southwest of the planet this month. Jupiter remains among the stars of Ophiuchus, near the southernmost part of the ecliptic.

Through a telescope, Jupiter's disk appears 35" across and shows lots of atmospheric detail, particularly if you wait until the planet climbs high in the sky before dawn. Look for two parallel, dark equatorial belts. Finer belts and zones come into view with prolonged viewing. Jupiter's four major moons — Io, Europa, Ganymede, and Callisto — flit around Jupiter. Each night, this quartet appears in a different arrangement.



SATURN'S MOONS appear in different places every night, as they orbit the ringed world in periods as short as 1 day. February 10 provides a good opportunity to see the seven brightest moons.

Mars appears in the morning sky among the background stars of Sagittarius. In early February, it stands north of Sagittarius' Teapot handle. As the month progresses, it moves toward Capricornus. On the 14th, a thin crescent Moon lies 9° to Mars' right. Mars shines at magnitude 1.3 this month, and its 4"-diameter disk reveals practically no detail through a telescope. The Red Planet slowly brightens and grows larger throughout 2007, reaching its peak in December.

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The TMB 5.1" triplet apo is a *2007 Hot Product !*

Tired of being on a multi-year waiting list for apo optics that never come? Here's a better idea. The 130mm f/7 **TMB Optical TMB-130** triplet apo – a *Sky & Telescope Hot Product for 2007* that's available now!

The superb **TMB-130** *Signature Series* refractor uses premium FPL-53 ED glass in its fully multicoated air-spaced triplet lens for a level of apochromatic color correction that impresses even its creator, renowned optics designer Thomas M. Back.

It has a collimatable temperature-compensated lens cell; a rotating 4" dual-speed rack and pinion focuser ideal for 35mm, medium format, and CCD photography; 2" and 1.25" compression ring eyepiece holders; retractable lens shade; dust covers; and a fitted hard case. It's available and priced right!

New lower prices on the Meade LX90 GPS.

Meade LX90GPS 8", 10", and 12" go-to Schmidt-Cassegrain telescopes with multi-coated UHTC optics have GPS (Global Positioning Satellite) technology to make it even easier for you to find your way around the sky.

And they have lower prices to make owning one easier on your wallet, too.

You don't have to tell an LX90 where or when you are on earth to find any of the more than 30,000 celestial wonders in its memory. Its GPS receiver gets that information from a net of 24 Earth-orbiting satellites, then moves to two alignment stars – *all automatically!*

Simply check that your either of your LX90's two finders are centered on those two stars, then start observing. The Meade LX90GPS makes astronomy that simple!

Since we keep the LX90 in stock, we can ship to you faster than dealers who have to order them in from Meade (and if you live in California, that saves you the sales tax, too).

Here are the *freight-paid* prices on the LX90s that we ship immediately from our stock:

8" LX90GPS, UHTC optics **$1999**
10" LX90GPS, UHTC optics **2699**
12" LX90GPS, UHTC optics **3299**

You'll find thousands of *unbiased* equipment reviews at www.cloudynights.com

The Orion StarShoot Deep Space CCD is cool(ed).

The **Orion StarShoot** is a single-shot full color CCD camera. Unlike other CCDs in its price range, it has a built-in thermoelectric cooler for cleaner and less noisy warm weather pics. It's cool and cooled for $399.95.

Your car's back seat will hold a 16" Meade LightBridge.

Meade LightBridge Dobsonians use a truss-tube design that lets even the big 16" model break down into a few small packages that fit into most compact cars.

All LightBridge Dobs have a 2" machined aluminum Crayford focuser; 1.25" eyepiece holder; 2" 26mm 70° field QX eyepiece, and an illuminated finder with four reticle patterns. Roller bearings provide smooth hitch-free motion at the touch of a finger. A battery-operated fan on the metal primary mirror cell assures fast cooling of the diffraction-limited BK7 optical glass mirror. No tools are needed to assemble and break down each scope in the field.

The prices below include the shipping from the Meade factory.

8" f/6 LightBridge **$599**
10" f/5 LightBridge **799**
12" f/5 LightBridge **999**
16" f/4.5 LightBridge **1999**

Is this Paragon the ultimate wide field eyepiece?

Many buyers believe that the 2" 40mm **TMB Paragon** – first in a series of Paragon focal lengths – truly *is* the best ever.

It has a wide 68° true field, tack-sharp images edge to edge, good eye relief, and great contrast. A reviewer said his first impression of M13 in the Paragon at 35x "was of a pinch of diamond dust on a black background; even at this low magnification, it was possible to see the 'dust' as a cloud of pinpoint stars."

Paragon redefines the wide field viewing experience, at a price/performance ratio no other quality eyepiece can touch.

At ***astronomics***, we specialize in telescopes and always have. Our family-owned business has been helping people choose the right telescope since 1979. We have the experience (a staff total of over *150 years* of experience

Go ahead. Give in to your urge to own a TeleVue.

You can admit it. It's nothing to be ashamed of. Everyone gets the uncontrollable urge to own some of Al Nagler's state-of-the-art optics sooner or later. Well, why not give in to temptation right now? Your eyes will thank you. And you won't have to wait to assuage your TeleVue urge, because *we stock a six-figure TeleVue inventory at* ***astronomics***.

Here are a few of the TeleVue apochromatic refractors that we normally stock.

TV-60, 2.4" f/6 doublet **$825**
TV-76, 3" f/6.3 doublet **1320**
TV-85, 3.35" f/7 doublet **1750**
TV-102, 4" f/8.6 doublet **2250**
Renaissance 102, 4" f/8.6 brass .. **3250**
NP-101, 4" f/5.4 Nagler-Petzval **3685**

And the new photo/visual *imaging system* apo refractors are available in limited quantities. They come with a larger non-vignetting focuser, Focusmate, photo accessory adapter, carrying case, and more.

TV-60is, 2.4" f/6 doublet **$1695**
TV-102iis, 4" f/8.6 doublet **2985**
NP-101is, 4" f/5.4 Nagler-Petzval .. **3985**
NP-127is, 5" f/5.2 Nagler-Petzval .. **6985**

Combine TeleVue and Vixen for premium grab-and-go.

When the sudden urge to observe hits you, don't settle for second-best optics. Enjoy premium TeleVue apochromatic optics on a convenient Vixen "pick up in one hand and go" Porta altazimuth mount and save $110 over the cost of buying the components separately.

Choose from a 60, 76, or 85mm TeleVue refractor with superb apo (color-free) optics on an adjustable height Vixen mount with 360° slow motion controls. Even the biggest system weighs only 20.5 pounds, so they're easy to pick up in one hand and take anywhere – around the world or just out to your back yard for a quick peek.

Here are the TeleVue refractor/Vixen Porta mount packages that we stock.

TV-60, 2.4" f/6 apo, black **$1165**
TV-76, 3" f/6.3 apo, ivory or green **2065**
TV-85, 3.35" f/7 apo, ivory or green **2490**

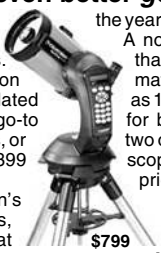
Scope, drive, 2 eyepieces, $209. No kidding.

With this **Konus**, how much you get for how little you pay is downright amazing.

If you just want a good scope for occasional casual observing, this 90mm (3.5") **Konusmotor-90** f/11 refractor is a great buy. It has an equatorial mount with adjustable tripod, a 6 x 30mm finderscope, battery-powered motor drive, and *two* 1.25" Plössl eyepieces!

It's a favorite with beginners because it's such a great value at only $209. And there are other Konus motor drive scopes from $109 to $799.

In 1979, a coffee cost 25¢ and a Celestron 8 cost $1295. Today, $1399 buys an even better *go-to* Celestron 8.



As for the price of coffee, you practically have to mortgage your house to pay for a cup at Starbucks.

A state-of-the-art 1979 Celestron would cost $3667.08 in today's inflated dollars – but it wouldn't have a go-to computer, DC drive, multicoatings, or a Plössl eyepiece like today's $1399 **Celestron NexStar 8 SE.**

But it *would* still have Celestron's superb Schmidt-Cassegrain optics, however. That's one advantage that hasn't changed over the years.

Unlike coffee and gasoline and all the other little necessities of life, the cost of a Celestron has actually *deflated* over the years. You get more, but you pay less.

A no-guesswork *SkyAlign* computer that finds sky objects for you automatically to make astronomy as easy as 1-2-3. Starbright XLT multicoatings for brighter images. These are just two of the features on the **NexStar SE** scopes that were unavailable at *any* price only a few short years ago.

Celestron NexStar SE scopes. Great values? *Yes!* And here are the models we keep in stock:

NexStar 4 SE, 4" Maksutov **$599**
NexStar 5 SE, 5" SCT **799**
NexStar 6 SE, 6" SCT **999**
NexStar 8 SE, 8" SCT **1399**

Celestron *SkyAlign* makes astronomy as easy as 1-2-3.

You don't need to know the Pleiades from Polaris to find your way around the skies with a **Celestron SLT** go-to scope. With Celestron's *SkyAlign,* just point your SLT at any three of the 50 brightest lights in the sky (3 stars, or 2 stars and a planet or the Moon), and the SLT finds 4,000 heavenly sights for you *automatically.* A few anonymous points of light are all you need to find the sky's wonders like a pro.

Each of the following *SkyAlign* SLT scopes has *two* eyepieces, red dot finder, motor drives, stainless steel tripod, computer hand control, and software to control the scope from your home computer.

NexStar 60, 60mm refractor **$279**
NexStar 80, 80mm refractor **379**
NexStar 102, 102mm refractor **479**
NexStar 114, 114mm reflector **399**
NexStar 130, 130mm reflector **439**

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using and selling telescopes) to help *you* pick the telescope that fits your needs (and your budget). And, with our seven-figure inventory, we can usually ship you the right scope, right away, from the hundreds we stock.

The $69.95 Astro-Tech diagonal is a *2007 Hot Product,* but truth be told, these could *all* be called hot products.

The **Astro-Tech** *dielectric* 1.25" star diagonal was named a *2007 Hot Product* by *Sky & Telescope.*

Like *all* the hot Astro-Tech diagonals, it has advanced 99% reflectivity *46-layer* dielectric coatings on its 1/10th wave BK7 optical glass substrate, plus a brass compression ring eyepiece holder that won't scratch your eyepieces.

The 2" diagonals have either a 2" barrel for refractors or a threaded ring that connects to a Schmidt-Cassegrain rear cell, plus a separate non-marring compression ring adapter for 1.25" eyepieces.

The 2" *quartz* diagonals provide 1/10th wave peak-to-valley surface accuracy – *even after being coated* – and include a Zygo interferogram as proof of performance.

Here are the prices of the **Astro-Tech** *dielectric* diagonals that we stock:

1.25" – *a Hot Product for 2007*	**$69.95**
2", with 1.25" adapter	**139.95**
2" SCT, with 1.25" adapter	**149.95**
2" quartz, with 1.25" adapter	**189.95**
2" quartz SCT, with 1.25" adapter	**199.95**

Astronomics helps you find Orion without a star chart.

We're not talking about the constellation of Orion.

We're talking about **Orion** telescopes and accessories.

$179.95

We stock Orion Dobsonian reflectors in all sizes. For the kids, there's the **SkyBlast** 4.5" f/4 tabletop model to the left, and the full-size 4.5" SkyQuest f/8 Dob, not shown, at $229.95.

We also stock the **SkyQuest Intelliscope** 6" to 12" Dobs that start at $479.95 (the 12" is shown to the right). Each comes with a hand-held *Intelliscope* object locating computer that quickly leads you to over 14,000 celestial objects, a laser collimating tool, a right-angle finderscope, and *two* Sirius 1.25" Plössl eyepieces.

$1099.95

If you have your own quality optics, such as TMB-130 apo refractor or a big SCT optical tube, this 40 lb. payload capacity **Orion Atlas-GT** *go-to* equatorial mount will carry them nicely for $1429.95. It's the ideal step between low price/small payload mounts and big payload mounts at big budget-busting prices. You can even train the Atlas mount's go-to computer to find objects with 1 arc minute accuracy!

Orion Atlas-GT mount
$1429.95

"Ritchey-Chrétien-like" Meade performance . . . at only a fraction the cost of a true R-C.

Meade 8" f/10 LX200R Ritchey-Chrétien
$2699 *freight paid*

Sky & Telescope said the new Meade catadioptric "does indeed perform like a Ritchey-Chrétien." And *Astronomy* said it "delivers Ritchey-Chrétien-like performance at a fraction the cost."

Why pay $14,000 to $34,000 for the flat field of a true Ritchey-Chrétien reflector optical tube – and still have to pay for a mount? Get the catadioptric that reviewers call "Ritchey-Chrétien-like" in a complete scope/go-to mount combo starting at under $2700!

8" to14" Meade LX200R go-to scopes usually ship from our stock, so you can get yours fast. And if you live in California, that saves you the sales tax, too.

Here are the *freight-paid* prices on the LX200R Meades that we ship from our stock:

8" **LX200R,** with UHTC optics	**$2699**
10" **LX200R,** with UHTC optics	**3699**
12" **LX200R,** with UHTC optics	**4699**
14" **LX200R,** with UHTC optics	**6499**

Because of their weight, these 16" LX200R scopes ship to you via truck from Meade.

16" **LX200R,** without mount, w/UHTC	**$11,529**
16" **LX200R,** tripod, w/UHTC	**12,999**
16" **LX200R,** altaz pier, w/UHTC	**12,524**
16" **LX200R,** eq pier, w/UHTC	**12,779**

I appreciate your help and, above all, your honesty! It is very refreshing to be treated fairly when it would be so easy for you to get away with not doing so due to my ignorance about how things should be in this new (and expensive) hobby of mine. It is the sort of treatment that brings customers back over and over with a feeling that they are glad to support your business.

Customer Quote of the Month #179

Hot in December. Still hot today.

$399

One of the hardest gifts to find last December was the **Celestron SkyScout**. It's still in short supply, but you'll be able to get yours before spring gets here.

This non-magnifying handheld personal planetarium locates the more than 6,000 celestial objects visible to the unaided eye, then tells you about them – *literally.* While earbuds talk to you about what you're looking at, you can read the scrolling 5-line text/graphics display.

The GPS-based SkyScout makes the night sky as familiar to you as your own back yard. You and your family will love it.

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Astro-Tech. The little telescope that could.

The image below was taken through the $329 **Astro-Tech AT-66ED** 66mm refractor. You'll find the full size, full color version on our **www.astronomics.com** website. Just enter "AT66" in the quick search box to get to the scope and click on the links in the scope copy to get to the original full color 20" tall image.

While you have that image open, open another web browser, go to Google images and enter "NGC7000" in the search box. Compare the image taken through the $329 Astro-Tech AT-66 to any of the hundreds of North American Nebula images shown on Google. Then ask yourself, "Who needs a $6700 refractor, 300mm reflector, or any of the other big and expensive scopes that took the other pictures when you can get images as good as the AT-66 can take for only $329?"

$329
Astro-Tech AT66ED, in brass, chrome, black, blue, green, red, burnt orange, or white

The **Astro-Tech AT-66ED** has superb 66mm f/6 ED optics, rotating dual-speed Crayford focuser, your choice of eight tube colors, and a hard carrying case. It's an amazing value at only $329!

There's also a *2007 Hot Product* 1.25" *dielectric* diagonal at $69.95, an 80mm Astro-Tech ED refractor at $529, and more. And bigger scopes are on the way!

Photo courtesy Sean Walker: Astro-Tech AT-66, SBIG STL-11000

An SBIG camera took the picture above.

$1395
SBIG ST-402XME

Sure, it was one of the big SBIG CCD cameras on that $329 Astro-Tech scope, but you don't have to buy a big SBIG to get SBIG quality and ease of operation.

The **SBIG ST-402XME** shown has the bells and whistles of a big SBIG camera, but a smaller price.

The 402XME has an advanced *microlens* CCD imaging chip that uses a tiny lens over each camera pixel to focus the light and increase sensitivity. Its CCD chip has a 765 x 510 array of 9 micron pixels with no column defects, high speed USB electronics, thermoelectric cooling with a built-in whisper fan, and more.

The monochrome version of the ST-402XME is only $1395. With a factory-installed internal color filter wheel, it's $1595. Either way, you get quality images and SBIG's traditional ease of operation at a very attractive price.

Quality SBIG CCD cameras are priced from $1395 to $12,995.

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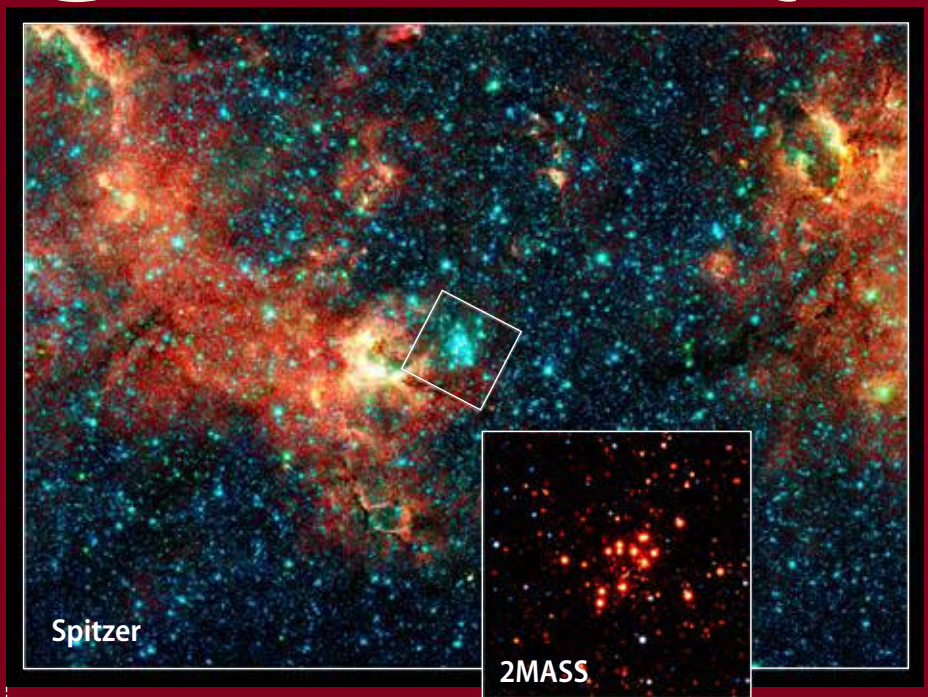
How astronomers glimpse the naked galaxy

By observing in infrared wavelengths, astronomers peer through obscuring dust and reveal the Milky Way's spiral structure.

/// BY ROBERT BENJAMIN



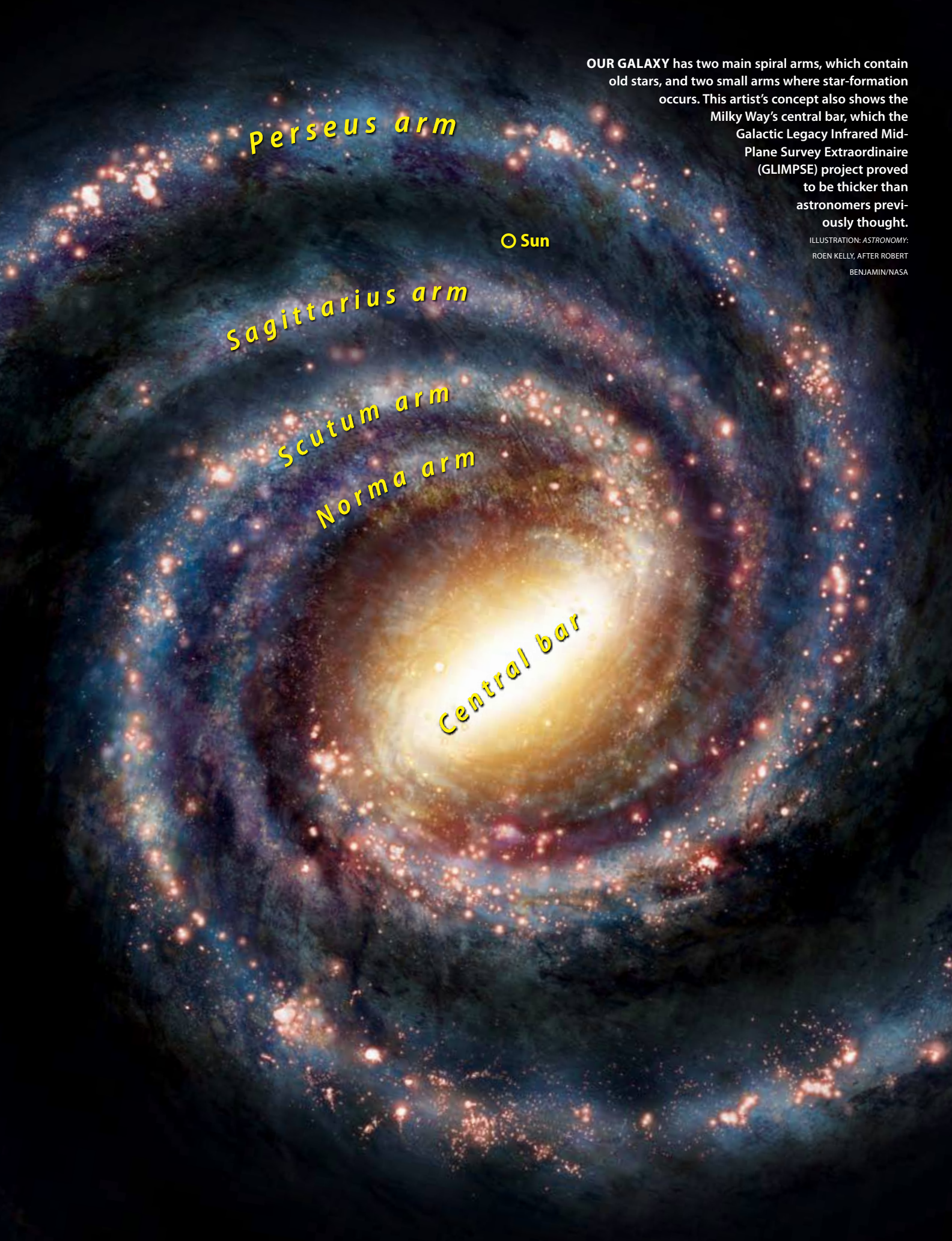
A NEVER-BEFORE-SEEN star cluster resides 18,900 light-years away. Spitzer's Infrared Array Camera took the wide-field view (which shows evolved stars as blue), and the 2MASS survey captured the inset. Both images show 14 supergiant stars — each 20 times the Sun's mass — about to explode as supernovae. NASA/JPL-CALTECH, D. FIGER (STScI/ROCHESTER INSTITUTE OF TECHNOLOGY), E. CHURCHWELL, B. BABLER, M. MEADE, AND B. WHITNEY (UNIV. OF WISCONSIN), AND R. INDEBETOUW (UNIVERSITY OF VIRGINIA), 2MASS

At the beginning of the 20th century, astronomers thought the Milky Way encompassed the entire universe. During the past century, as astronomical understanding has raced ahead to decipher the evolution of stars, other galaxies, and the universe itself, the Milky Way has given up its secrets only grudgingly.

Because the galaxy surrounds us, understanding its structure entails observing a large fraction of the sky. In the past, this required decades of data collection and analysis. Now, thanks to advances in detector technology, analysis software, and computing power, it has become feasible to complete such surveys in a few years.

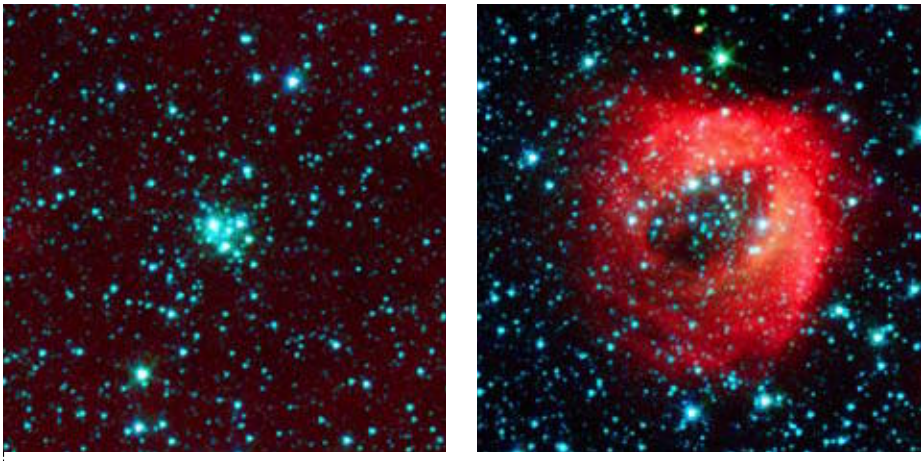
On August 25, 2003, NASA launched the Spitzer Space Telescope on a mission to study the universe in infrared

Robert Benjamin *is a physics professor at the University of Wisconsin-Whitewater and the principal investigator of GLIMPSE-3D, a follow-up project to study the vertical stellar and interstellar structure of the inner Milky Way.*



OUR GALAXY has two main spiral arms, which contain old stars, and two small arms where star-formation occurs. This artist's concept also shows the Milky Way's central bar, which the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE) project proved to be thicker than astronomers previously thought.

ILLUSTRATION: *ASTRONOMY*: ROEN KELLY, AFTER ROBERT BENJAMIN/NASA



GLIMPSE uses an automatic cluster-finding computer program developed by astronomers at Boston University. This software searches large areas of sky to find different-looking clusters difficult for the eye to pick out. At left is an isolated, tight grouping of stars. The right image shows a looser cluster situated within a wispy red ring, which glows because of the cluster's radiation. NASA/JPL-CALTECH/E. MERCER (BOSTON UNIVERSITY)

wavelengths. Three years prior to Spitzer's launch, NASA chose six large observing programs — dubbed "Legacy" projects — after a worldwide call for proposals. One of these, the Galactic Legacy Infrared Mid-Plane Survey Extraordinaire (GLIMPSE), surveys the Milky Way in four infrared spectral ranges.

GLIMPSE-ing the sky

The area covered by GLIMPSE contains most of the galaxy's star-forming regions and about 70 percent of its molecular gas. The GLIMPSE team focuses on two questions: What do the distribution of stars and infrared-bright star-formation regions tell us about the inner galaxy's structure, including the disk, molecular ring, number and location of spiral arms, and central bar? What are the physics of star formation as a function of mass, stage of evolution, and location in the Milky Way?

The problem with star counts

When it comes to determining the distribution of stars in the Milky Way, the most straightforward technique is simply to count stars. English astronomer William Herschel (1738–1822) introduced this technique in 1765. Historically, however, star counting has led to some of the most famous wrong answers in astronomy.

Imagine we live in a galaxy comprising a disk of stars (we do), and that we are closer to the edge than the center (we are). As we scan the galactic plane, we should see the most stars when we look toward the galaxy's center (we don't). By looking at how quickly the number of stars declines as we scan away from the galaxy's center, astronomers should be able to determine how the stellar density decreases (we can't). When we look in directions for which our line of sight skims tangent to a spiral arm, we should see an excess of stars compared to nearby directions (we don't).

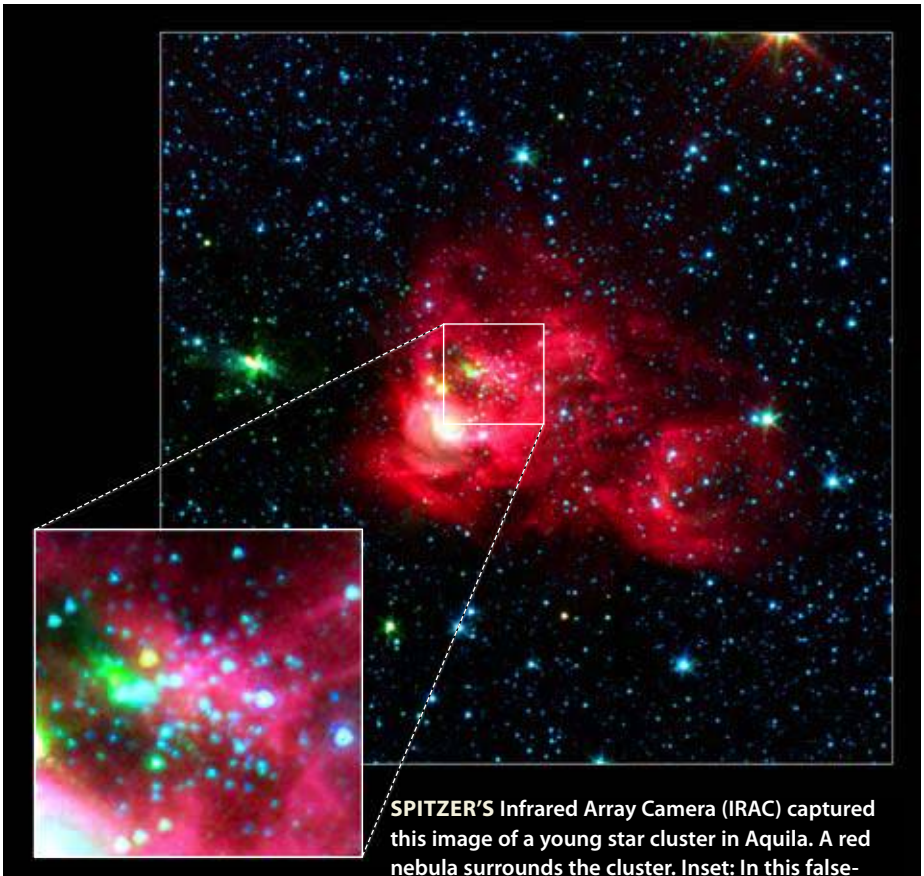
What's wrong? The answer is one of the unpleasant four-letter words of astronomy: dust. Although the density of dust (and gas) in interstellar space is nearly nothing, space is vast, and a whole lot of nearly nothing adds up to something.

What effect does dust have? Imagine watching a sunset. The Sun reddens and dims as it approaches the horizon, and your ability to measure the Sun's true color and brightness is impaired. In interstellar space, the Milky Way's dust is not evenly distributed but occurs in clumps and clouds. A few "holes" exist through which astronomers can observe stars to great distances. One such area, called Baade's Window, named for German-born American astronomer Walter Baade (1893–1960), allows a view of the Milky Way's central bulge. But for most of the galaxy's inner disk, dust is a showstopper — a barrier to understanding the distribution of stars there.

Through the dust

The barrier began to crumble with the advent of sensitive infrared detectors. Because infrared light penetrates dust more readily than visible light, an infrared view

THIS PANORAMIC IMAGE from GLIMPSE shows a great deal of stellar activity in the Milky Way's plane. The image spans 9° of sky (by 2° tall), about as much as the width of your fist held at arm's length. This region represents only 7.5 percent of the GLIMPSE survey, which imaged most of the star-forming regions in our galaxy. The red clouds show the presence of large molecules illuminated by nearby stars. NASA/JPL-CALTECH/E. CHURCHWELL (UNIV. OF WISCONSIN)



SPITZER'S Infrared Array Camera (IRAC) captured this image of a young star cluster in Aquila. A red nebula surrounds the cluster. Inset: In this false-color composite, reddish wisps are organic molecules illuminated by nearby stars. Green indicates hot hydrogen, and blue reveals older stars. NASA/JPL-CALTECH/E. MERCER (BOSTON UNIVERSITY)

of the galaxy reveals more stars. The Diffuse Infrared Background Experiment aboard the Cosmic Background Explorer (COBE), launched in 1989, could not resolve individual stars. However, several groups analyzed the light distribution and found evidence for a central stellar bar in our galaxy. Now, using the unprecedented sensitivity of the Spitzer Space Telescope, astronomers can study the galaxy at the same wavelengths but with enough angular resolution to observe individual stars.

Using the Infrared Array Camera, the GLIMPSE Legacy team, led by Ed Churchwell of the University of Wisconsin, is surveying a 130°-long strip stretching 1° above and below the galactic plane. This strip contains most of the galaxy's stars. Unfortunately, it also contains most of the dust. The project's goals were to take a stellar census of the galaxy and study star formation.

The team's stellar census is complete. It produced a catalog of more than 40 million sources in four different wavelengths. Scientists expect more than 90 percent of these sources to be red giant stars. Because red giants are so luminous, they can be seen from large distances across the galaxy. Although dense regions of dust still block our view, even in the mid-infrared — one of the pleasant results of this survey is that the star-counting technique actually works.

By counting stars as a function of direction and brightness, GLIMPSE found the long-expected result that the number of stars increases all the way to the galactic center. This enables astronomers to measure the radial "scale length" of the galaxy — the distance one has to go from the center for the stellar density to drop by a factor of nearly 2. By determining this number

THE MILKY WAY'S STELLAR COMPONENTS

GALAXIES

Galaxies are stellar "islands" in a largely empty universe. Their stars, gas, and dust are organized into different components, each of which tells us something about how disk galaxies, like the Milky Way, form and evolve.

THIN AND THICK DISKS

The largest percentage of stars in the galaxy are in a disk — a thin (600-light-year-thick) disk where the star density drops as one gets farther from the galactic center. GLIMPSE measures a radius for the Milky Way's disk of roughly 12,700 light-years. Galaxies like the Milky Way also have a low-density thick disk of stars.

SPIRAL ARMS

Nearly all disk galaxies show some evidence of spiral structure with an overdensity of stars in the spiral arms.

BAR

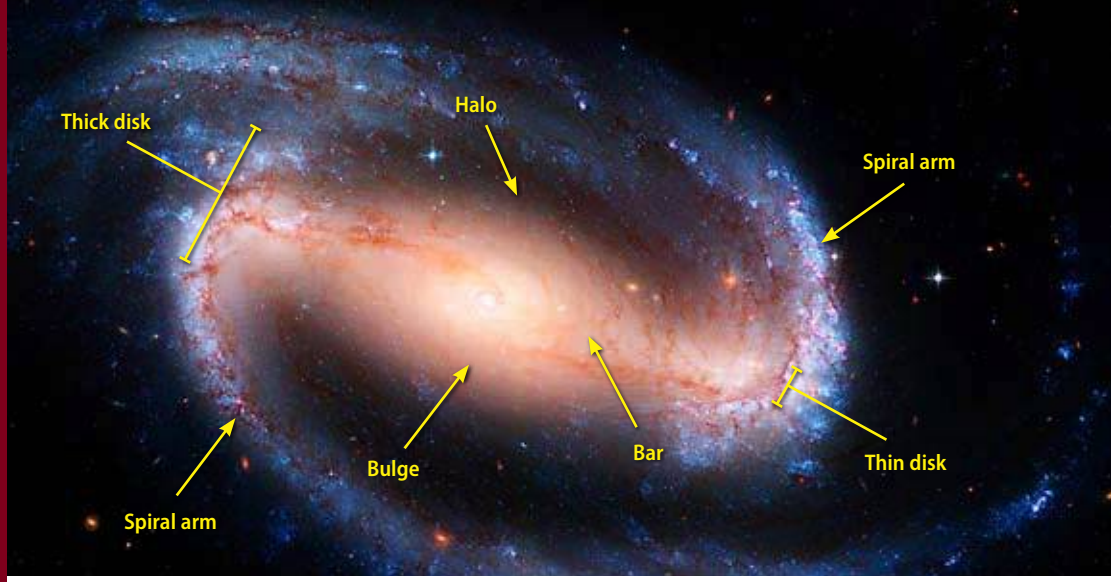
In infrared wavelengths, astronomers observe nearly 80 percent of all galaxies have a central bar of stars. This bar consists of a large group of stars moving in skinny (high-eccentricity) elliptical orbits around the galaxy's center.

BULGE

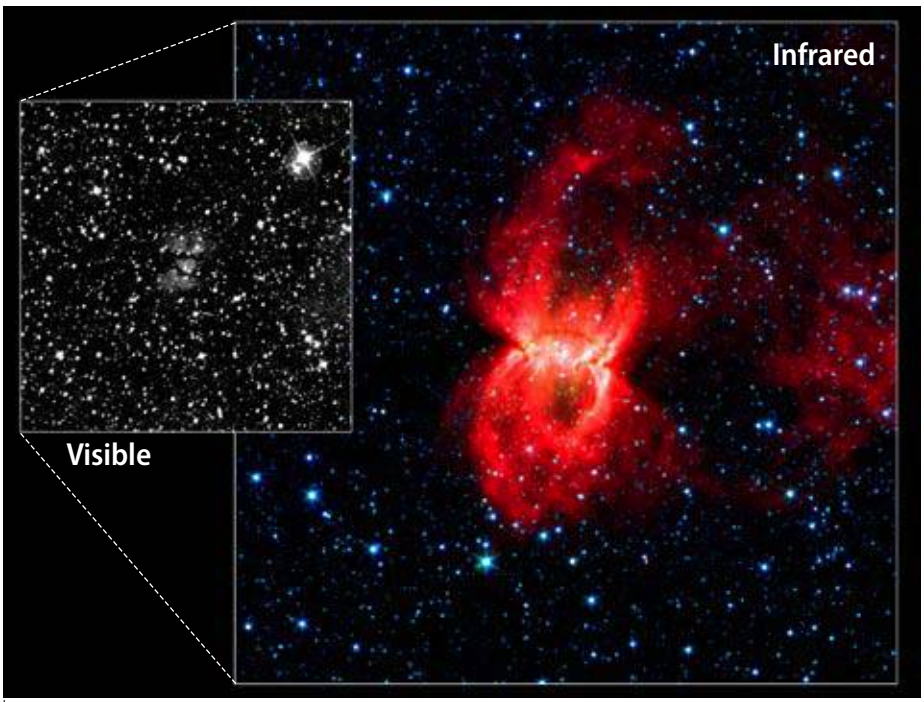
In addition to the bar, most spiral galaxies have a dense central bulge of stars. This bulge is frequently elongated along one axis, rather than being spherical.

HALO

The Milky Way also is surrounded by a low-density gigantic (600,000-light-year-wide) halo of stars. Astronomers think this halo contains important clues on how our galaxy formed.



THE MILKY WAY used to be classified as a spiral galaxy. Recently, the GLIMPSE observing program undertaken by the Spitzer Space Telescope confirmed the existence of a bar. For definitions of the terms above, see the column at left. NGC 1300: HUBBLE HERITAGE TEAM/ESA/NASA

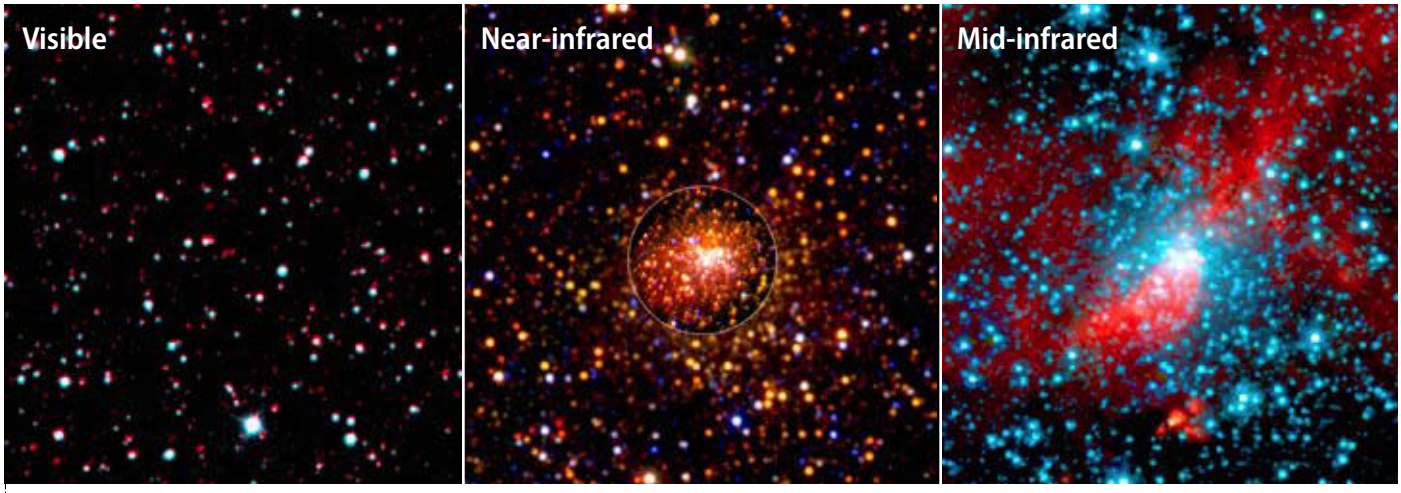


WHAT A DIFFERENCE infrared light makes. Compare these two images of the Black Widow Nebula in the southern constellation Circinus the Compass. The smaller image is a visible-light exposure taken by the Digital Sky Survey. The larger image, taken with Spitzer's Infrared Array Camera, shows powerful outflows of radiation from massive groups of stars sculpting two opposing gas bubbles. Where the bubbles overlap, new stars appear as yellow specks. NASA/JPL-CALTECH/E. CHURCHWELL (UNIV. OF WISCONSIN), DIGITAL SKY SURVEY

and studying how the galaxy's rotation speed varies at different radii, astronomers can infer how much of the inner galaxy is in the form of dark matter (matter that neither emits nor reflects enough radiation to be detected).

Raising the bar

GLIMPSE also has shed light on two of the major structural features of our Milky Way. First, astronomers counted the number of stars at equal angles to the left and right of the galactic center and examined their brightnesses. These GLIMPSE data confirmed the galaxy has a long stellar bar. This bar is characterized by an excess population of stars called "red giant clump" stars. These stars, which shine with a fixed luminosity, were used as "standard candles" to pin down the bar's angle and length.



THESE IMAGES show the same patch of sky in various wavelengths of light. While the visible-light image (left) shows a dark sky speckled with stars, infrared images (middle and right), reveal a never-before-seen bundle of stars, called a globular cluster. Spitzer's Infrared Array Camera took the right image as part of the GLIMPSE project. NASA/JPL-CALTECH/H. KOBULNICKY (UNIV. OF WYOMING)

THE INFRARED ARRAY CAMERA (IRAC) aboard the Spitzer Space Telescope takes images covering a 26-square-arcminute area, or, for comparison, about 3 percent of the area of the Full Moon. IRAC images in four infrared channels simultaneously. The channels' wavelengths center on 3.6, 4.5, 5.8, and 8 micrometers. IRAC's only moving part is its shutter. NASA/JPL-CALTECH

SPITZER SPACE TELESCOPE LEGACY PROGRAMS

Spitzer Space Telescope operation will last approximately 5 years, until the liquid-helium fuel necessary for its detectors is exhausted. To ensure key projects would be accomplished, NASA held a competition for a set of large-scale programs collectively called Legacy. The agency makes the Legacy programs data available to everyone. The data will be useful for astronomers for decades. NASA selected these six programs:

LEGACY PROJECT	ABBREVIATION	PRINCIPAL INVESTIGATOR	STUDIES
Galactic Legacy Mid-Plane Survey Extraordinaire	GLIMPSE	Ed Churchwell, University of Wisconsin	Stellar content and star formation in the inner Milky Way.
From Molecular Cores to Planet Forming Disks	C2D	Neal Evans, University of Texas	Details of star formation in nearby molecular clouds.
Formation and Evolution of Planetary Systems	FEPS	Michael Meyer, University of Arizona	Different planetary systems around stars of different ages.
Spitzer Infrared Nearby Galaxy Survey	SINGS	Rob Kennicutt, Cambridge University	Structure and star formation in a sample of nearby galaxies.
Spitzer Wide-Area Infrared Extragalactic Survey	SWIRE	Carol Lonsdale, Caltech	Evolution of galaxies in a 50-square-degree swath of the sky.
Great Observatories Origins Deep Survey	GOODS	Mark Dickinson, University of Arizona	Formation and evolution of galaxies in the early universe.

Although other astronomers observed the bar, the sensitivity and full coverage of GLIMPSE provided a dramatic confirmation of the bar's structure.

The second surprise lurking in GLIMPSE star counts concerned our galaxy's spiral structure. The survey's outer regions contained two areas where astronomers expected to see an excess of stars because our line of sight skims along spiral arms at these points. One of these arms, the Scutum (or, Scutum-Crux) arm, shows a dramatic enhancement of stars in exactly the direction expected from studies of star-forming regions in optical and radio wavelengths. But the second region, the Sagittarius (or, Sagittarius-Carina) arm tangency, shows no strong evidence for such an enhancement. This is despite the fact that both tangencies are located approximately the same distance from the Sun.

Although the Sagittarius arm is clearly a major star-forming structure, it lacks any evidence of compression in the older stellar populations. Ron Drimmel and David Spergel of Princeton University first noted this using COBE data. Astronomers have noted this characteristic in other spiral galaxies as well because infrared light traces the old stellar populations (and most of a galaxy's stellar mass), while visible light traces recent star formation. It sometimes happens that spiral galaxies show secondary star-forming compressions between the major infrared arms. Is our galaxy such a case? Time and future study will tell.

ONLINE EXTRA Enjoy more infrared Spitzer images at www.astronomy.com/toc.

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1 A protoplanet's fate

A protoplanet forms in the disk of gas and dust around a young star. It spirals inward toward the star thanks to the disk's gravity.

Protoplanet

Young star

Disk of gas and dust

When a planet grows to about 1/10 Jupiter's mass, its gravity opens a gap in the disk. This locks the planet's orbit to the disk's expansion and contraction, so the planet can migrate in either direction. Gravitational interactions with other planets may also shrink or enlarge its orbit.

Type I migration moves planets inward.

Type II migration moves planets both ways.

3 Jupiter and Saturn tango

Jupiter and Saturn migrated as they cleared out the young solar system's ice and rock debris. In simulations, Saturn migrates outward, eventually circling the Sun once for every time Jupiter orbits twice. In this 1:2 resonance, Jupiter's repeated tugs pump up Saturn's orbital energy and make its orbit more eccentric.

Neptune

Saturn

Pluto and the Kuiper Belt

Uranus

51 Pegasi

4.8 million miles (7.8 million kilometers)

51 Peg b

2 The first "hot Jupiter"

In 1995, astronomers discovered a planet half Jupiter's mass orbiting the Sun-like star 51 Pegasi. The planet orbits less than 1/8 Mercury's average distance from the Sun.

6 The late heavy bombardment

Trillions of comets and asteroids plunge toward the inner planets at just the right time — up to a billion years after formation — to account for the late heavy bombardment. The computer-simulated chaos, which lasts 100 million years, is as brief and as intense as the real thing, based on studies of the Moon's craters.

Asteroid belt

Jupiter

Sun

Earth

Asteroid

Venus

Sun

Mercury

5 Jupiter pitches asteroids

As Jupiter and Saturn move out of their 1:2 resonance and toward their present positions, their gravity pumps up the orbital energy of asteroids and nudges them into unstable orbits. Some careen into the inner solar system.

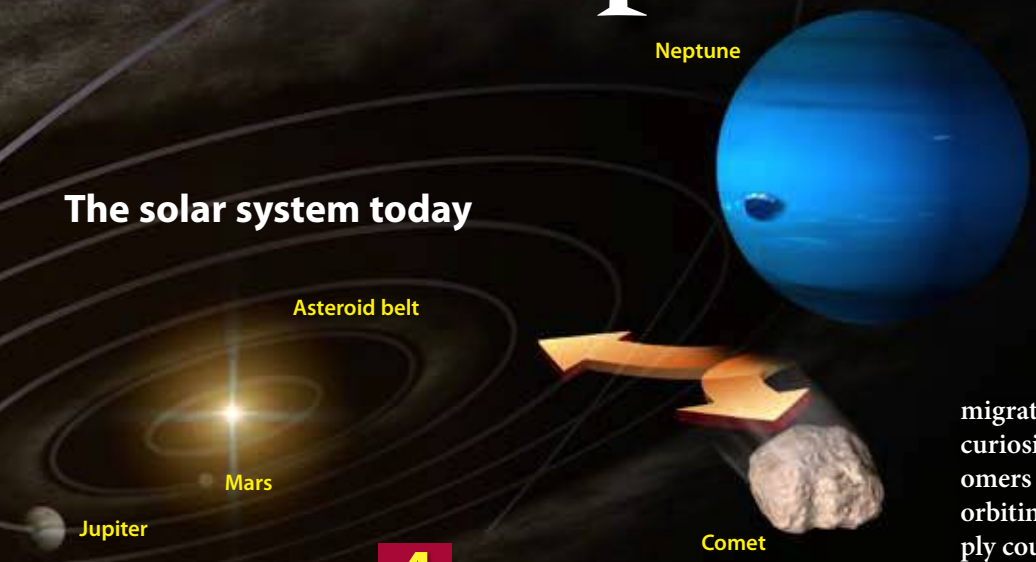
Astronomy magazine

When planets stray

Wayward worlds unleash a rain of ruin in their neighborhoods.

/// BY FRANCIS REDDY;
ILLUSTRATION BY DANA BERRY

The solar system today



4 Neptune tosses comets

Saturn now makes repeated close approaches to the next planet out. In the simulations, this is Neptune, not Uranus. Saturn quickly scatters Neptune out to where we find it today. There, Neptune plows through an undisturbed disk of comets and scatters them inward and outward.

7 Mystery solved?

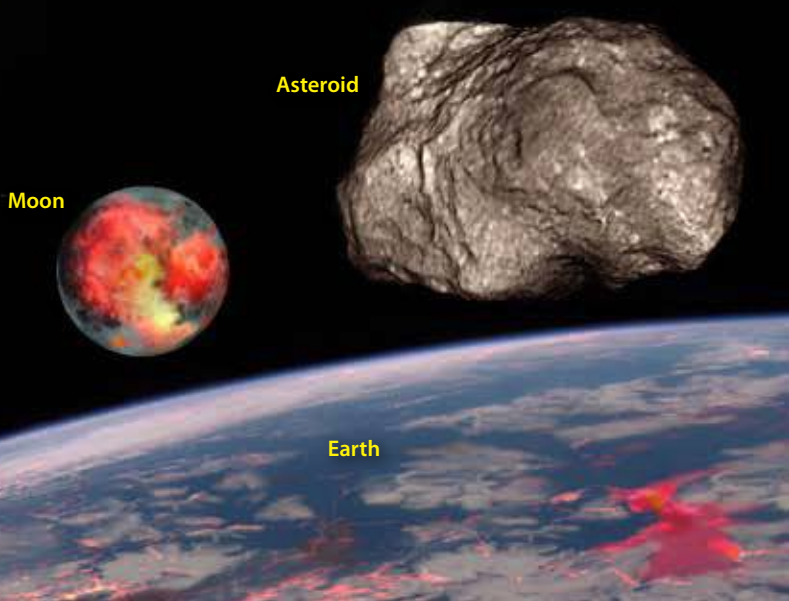
Scattering those asteroids and comets would have settled the giant planets into the paths we find them in today. Still, some scientists doubt a late heavy bombardment even happened. But if this cosmic calamity occurred, it arrived just as life was getting started on Earth. Did the solar system's wayward giants nearly eradicate life? Or did they trigger a pulse of impacts that somehow ensured its survival?

In the late 1970s, studies of how a planet's ring system and moons interact gave the first hints of a process now called planetary migration. It was little more than a theoretical curiosity until the mid-1990s. But then astronomers found gas-giant planets ("hot Jupiters") orbiting so close to their parent stars they simply couldn't have formed there. These worlds must have formed farther out and spiraled in toward their stars.

Did such an event take place in our own solar system? Computer simulations led by Rodney Gomes of the National Observatory in Rio de Janeiro and Kleomenis Tsiganis of the Observatory of the Côte d'Azure in Nice, France, suggest it did. The migration of Jupiter and Saturn seems a natural explanation for the tilt and eccentricities of all giant-planet orbits.

Moreover, a shake-up in the outer solar system may explain the late heavy bombardment, when comets and asteroids heavily pounded the inner planets between 3.9 and 3.8 billion years ago. The Moon's scarred face may be the aftermath of a giant-planet shuffle.

ONLINE EXTRA See a computer simulation of solar system migration at www.astronomy.com/toc.



These must-see stellar treats look their best in winter's crisp, clear air.

/// BY STEVE COE

Explore winter's 12 best star clusters

On clear winter nights, scanning along the Milky Way reveals many splashy objects. Although the air may be cold, you'll hardly notice the weather when you gaze at these stellar treats. So, set your telescope outside to cool, and get ready for a starry adventure.

Through binoculars, you'll see the Milky Way as irregular, with bright spots along its path. Many of these spots are open star clusters, the type of cluster that forms within galaxies' spiral arms.

French comet-hunter Charles Messier (1730–1817) listed the best of these clusters. Because Messier used a small telescope, he saw only the brightest. So, if a cluster has an "M" designation, it's generally a showpiece and one you'll want to point your telescope at. J. L. E. Dreyer's *New General Catalogue* (*NGC*), printed in 1888, contains many other clusters that make fine observing targets. The last of the 12 clusters outlined here is a favorite of mine from the Collinder listing. Swedish astronomer Per Collinder (1890–1974) compiled a catalog of 471 open clusters, published in 1931.

You can rate each cluster on various visual aspects. The amount of compression describes how closely packed the stars lie within the cluster. A compressed cluster requires higher magnification to resolve individual stars. The richness of an open cluster lets you know how many stars it contains. Only the best clusters display more than 50 stars.

Looking for features that stand out makes each star group different from those around it. Look for double stars in the cluster and stars that display strong color. Don't rush while viewing, and take some notes. This way, you really will observe these objects and not just check them off a list.

M35 AND NGC 2158 in Gemini make a great pair of clusters for low-power telescope views. NGC 2158 lies 0.5° southwest of M35 and shines 3.5 magnitudes fainter. Use at least a 10-inch scope and 150x to get the most out of NGC 2158. JOHN CHUMACK

Steve Coe *is a member of Phoenix's Saguaro Astronomy Club. His book,* Observing Nebulae *(Springer, 2006), highlights more sky targets.*

WINTER CLUSTER WATCH LIST

Object	R. A.	Dec.	Mag.	Size
M35	6h09m	24°21'	5.1	25'
M37	5h52m	32°33'	5.6	15'
M38	5h29m	35°51'	6.4	15'
NGC 1907	5h28m	35°20'	8.2	5'
NGC 2158	6h07m	24°06'	8.6	5'
NGC 2355	7h17m	13°45'	9.7	8'
NGC 2251	6h35m	8°22'	7.3	10'
NGC 2301	6h52m	0°28'	6.0	15'
M50	7h03m	–8°23'	5.9	15'
M41	6h46m	20°45'	4.5	39'
NGC 2362	7h19m	–24°57'	3.8	6'
Collinder 140	7h23m	–32°02'	5.3	42'

Key: R. A. = Right ascension (2000.0); Dec. = Declination (2000.0); Mag. = Visual magnitude; Size is estimated – larger telescopes will show more of a cluster's outer regions.

Start in Auriga

Let's start with one of the finest open clusters in the sky — **M37** (NGC 2099) in Auriga. Any optical aid will show it as a glowing spot. Through binoculars, you'll see two other bright clusters (M36 and M38) nearby. M37 lies closest to Gemini.

Through my 6-inch telescope with a 22mm eyepiece (40x), this cluster appears bright, large, rich, and compressed. Moving up in magnification with an 8.8mm eyepiece (105x), I can count 108 stars. A prominent set of dark lanes cuts the cluster into unequal thirds. A light orange star — HD 39183 — lies dead center.

Not quite 6° northwest of M37 lies **M38** (NGC 1912), an object less rich than M37. A prominent dark lane lies east of the cluster's center. With a 6-inch scope and an 8.8mm eyepiece, I resolved 43 stars. Look at the cluster's prominent stars for a shape many observers mention — the Greek capital letter Pi (Π).

The next cluster on the list lies 0.5° south of M38. **NGC 1907** measures only 5' across and glows at magnitude 8.2. Through my 11-inch telescope, it's quite compressed and demands 220x for a good view. I counted only 22 cluster stars. A thin dark lane bisects the cluster.

Move to Gemini

The Twins contains another bright Messier cluster, **M35** (NGC 2168). M35 shines at magnitude 5.1 and measures 25' across. With a 21mm eyepiece in a 4-inch f/6 scope (29x), I counted 66 stars. A prominent orange star lies at the cluster's northeast edge where a dark lane makes a V shape.

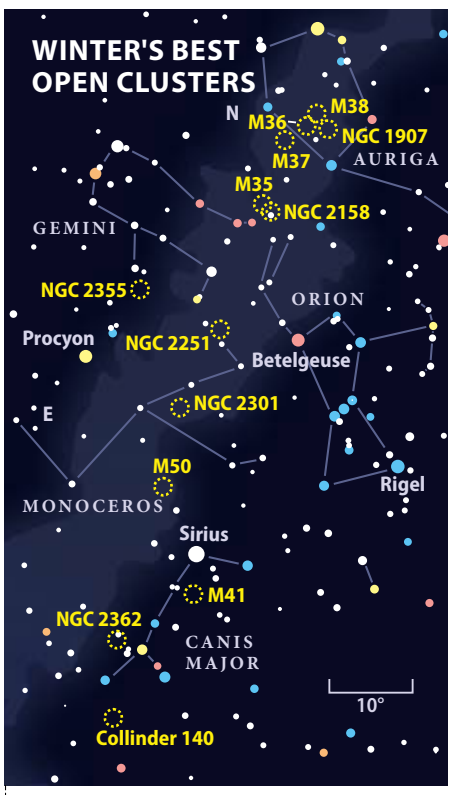
Moving up to the 6-inch scope and a 14mm eyepiece (65x), I counted 86 stars, including several beautiful chains that wind their way through this group. Instead of a concentration of stars in the middle, M35's core contains a dark triangular patch.

NGC 2158 lies less than 0.5° southwest of M35. Together, these two clusters make one of the most famous pairs of deep-sky objects visible through small telescopes.

NGC 2158 is a fairly high-surface-brightness object. This cluster looks like a small wedge through a 4-inch scope, but you won't resolve any stars.

I observed NGC 2158 through a 20-inch f/6 reflector at 280x. It was difficult to determine where the cluster ended and the Milky Way began, but I counted 55 stars.

NGC 2355 in Gemini appears bright and compressed. High power in a 6-inch scope reveals 16 stars, and 100x through my 11-inch showed 26 stars with a faint background glow. Moving up to 150x showed 32 stars. A delicate triple star — two magnitude 10 stars with a 13th-magnitude companion — sits on the east side.



THIS BAKER'S DOZEN (including M36 in Auriga) of winter's best open star clusters provides good contrasts in both size and brightness. For best results, observe from a dark site. *ASTRONOMY:* ROEN KELLY

M50 in Monoceros shines brightly enough (at magnitude 5.9) to be seen without optical aid by sharp-eyed observers from a dark site. M50 lies a bit more than 9° north-northeast of Sirius. NOAO

M41 in Canis Major sits 4° due south of the night sky's brightest star, Sirius. You'll spot this cluster easily with your naked eyes from a dark site, but it explodes with detail when viewed through a telescope. NOAO

Down to the Unicorn

NGC 2251 in Monoceros appears as a bright spot through 10x50 binoculars. Using my 13-inch Newtonian reflector at 100x, this cluster looks elongated and uncompressed. It contains 40 stars spread through a nice Milky Way field. A prominent dark lane cuts through the cluster.

NGC 2301 ranks as a winter favorite of mine; a rich star field surrounds it. Also, the cluster shines at magnitude 6, so it's easy to pick out. But, the cherry on top for me is H 740, a beautiful blue-and-yellow double star located dead center. Through my 6-inch at a dark site, I counted 33 stars, including the double star. Two magnitude 9 stars separated by 20" form this pair.

M50 (NGC 2323) is a Messier object that rarely makes anyone's list of best open clusters, but it's still a good target. Through a 6-inch and a 14mm eyepiece, I counted 31 stars. M50 is bright and detached from the Milky Way. An obvious magnitude 8 orange star sits on the cluster's south side.

End in Canis Major

Not only does **M41** (NGC 2287) shine brightly, you can use the sky's brightest star to help you find it. Under a dark sky, you'll see M41 easily with your naked eyes 4° south of Sirius (Alpha [α] Canis Majoris).

M41 glows at magnitude 4.5 and measures 45' across — 50 percent larger than the Full Moon. Use a 4-inch scope and low power to resolve 42 stars. This includes a bright orange star at M41's center. This cluster looks like celestial fireworks, with curving chains of stars winding out from the orange star in the center.

Once you see the **Tau Canis Majoris Cluster** (NGC 2362) in Canis Major, you'll never mistake it for any other. The reason is the 4th-magnitude triple star (Tau [τ] CMa) located in the middle. NGC 2362 shines brightest of the clusters featured here.

Through an 11-inch at low power, I counted 32 stars at 60x. Move past 100x to see Tau divide into 3 stars: a white 4th-magnitude primary with two magnitude 10 blue companions, both east of the bright member. No other cluster in the sky looks like NGC 2362. Don't miss it.

Collinder 140 measures 42' across and makes an easy naked-eye target. It is located 3° south of Eta (η) Canis Majoris, the star at the end of the Big Dog's tail.

With a 35mm eyepiece in my 4-inch telescope, Collinder 140 looks bright, large, and elongated. I counted 24 stars. This huge star cluster occupies about 60 percent of the field of view in my widest-field eyepiece. A nice yellow-and-blue double star — Dunlop 47 — lies in the middle.

Now it's your turn to explore these open clusters. Bundle up, head out, and give them a try. You won't be disappointed.

ONLINE EXTRA See more pictures of these clusters at www.astronomy.com/toc.

A few dollars can add value to your observing kit. /// BY MICHAEL E. BAKICH

Big bang for your astronomy bucks

About a year ago, members of the popular Internet astronomy group sci.astro.amateur began a discussion titled "The best $100 I ever spent." I asked members of that group, along with some other astronomy friends, to tell me about their best purchases — anything related to astronomy that cost $100 or less. The response was overwhelming.

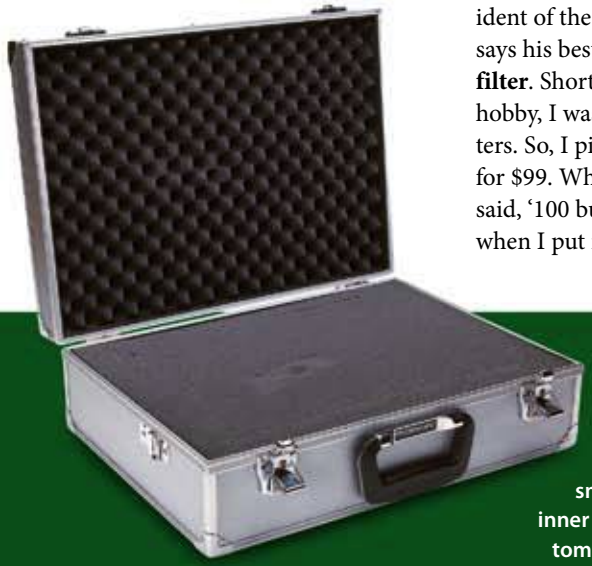
Dave Gede of Reisterstown, Maryland, didn't have to think for long. He writes, "The best money I ever spent on astronomy is the $25 to **join my local astronomy club**. The advice and friendships I've gained are priceless. From meeting world-class observers, to being motivated to look deeper than I ever thought possible, to working with the public through the Night Sky Network, I have spent thousands of dollars on this hobby. But joining the Westminster Astronomical Society has produced the best results."

Indeed, membership in an astronomy club provides lots of advantages. Amateurs are also quick to talk about their bargain equipment purchases. John Carruthers of Eastry, England, says, "My best buy was a **Burgess Optical/TMB 6mm Planetary eyepiece** (£45/$85). It is as sharp as any of my orthoscopics but has a 60° field of view and 20 millimeters of eye relief. I use it with my homebuilt 10-inch f/6.1 reflector, and it has made planetary viewing a real joy."

Craig M. Bobchin, 2005–2006 vice president of the Orange County Astronomers, says his best purchase was, "my first **nebula filter**. Shortly after I got back into this hobby, I was hearing all about nebula filters. So, I picked up a Lumicon UHC filter for $99. When I showed it to my wife, she said, '100 bucks for a piece of glass?' But when I put it into play she was surprised."

You also can find bargains on equipment that will help you aim your scope. Astroimager Anthony Ayiomamitis from Nea Palatia, Greece, summed up his choice: "My **Telrad [sight]** has made me a more productive observer and has relegated my finder scopes useless. This is especially true when I use it with telescope/eyepiece combinations that give a narrow field of view. Mint-condition Telrads are available on the resale market for $30 to $40."

Sometimes, a great buy on equipment has nothing to do with a scope. Cory Stone, assistant director of the Gene Roddenberry Planetarium in El Paso, Texas, says, "The best under-$100 astro-thing I've purchased was a camping accessory. I was faced with the fearsome reality that our club's dark-sky site is 50 miles from the nearest restroom.



ORION'S Pluck-Foam cases keep eyepieces, accessories, and even small telescopes safe. The inner foam is cubed for a custom fit. ($49.95) MICHAEL E. BAKICH

AN EYE PATCH relieves eye fatigue by letting you keep both eyes open while you're observing. ($3.95) MICHAEL E. BAKICH

BINOCULARS provide wide-field views of objects such as star clusters, the Milky Way, and meteor trails. (Approximately $89) *ASTRONOMY*: WILLIAM ZUBACK

LUMICON'S UHC filter cuts light pollution's effects by adding more contrast to deep-sky images. Such filters screw into the base of 1¼" or 2" eyepieces. ($99 for the 1¼" version) *ASTRONOMY*: WILLIAM ZUBACK

RIGEL SYSTEMS' StarLite astronomy flashlight uses two light-emitting diodes to create a red beam. The StarLite also is dimmable. ($20.95) MICHAEL E. BAKICH

So, I went to a nearby store's camping section and bought a small **trail potty** for $45.99. Holding a bed sheet around oneself allows near total privacy (and a break from the wind on delicate body parts not used to the elements). The first observer to use this convenience appreciated it, but still grumbled as she sat down to business, saying 'The things I do for science!'"

In some cases, spending less than $100 can dramatically alter your observing site. Doug Kniffen of Warrenton, Missouri, says, "For me, the worst light pollution comes from nearby lights. Shading a light can improve your dark-adaption. Beginning in 1993, I built four **light-blockers** that shade my backyard observatory. The tallest rises 27 feet and holds a 4' by 8' tarp. The others are shorter but hold larger tarps. I used two 2" by 4" poles for vertical support and four Nylon ropes to hold it vertical. The legs pivot on carriage bolts through posts set in the ground. The combination is amazingly strong and has withstood a number of 80 mph wind gusts."

Amateur astronomers know the easier they can make their routine, the more time they'll spend at the eyepiece. Veteran observer Susan Carroll of Bradenton, Florida, shares a little-known secret: "The best thing I ever spent money on was a handheld **mini-cassette recorder**. It proved invaluable when I observed the Messier, Herschel, and Herschel 2 lists. Yes, you do have to transcribe your dictation, but it sure beats having to write everything at night — running back and forth from the eyepiece to your log book. Then you blow your night vision because of the light you need to read. The average price for one of these units is about $20. It takes 2 AA batteries. A mini-cassette tape on slow (lower quality) gives you 1 hour of recording time per side. My recorder is even voice-activated."

For some, the best astronomy purchase was their first. If it's the right equipment, the inspiration it provides lasts a lifetime. *Astronomy* Contributing Editor Phil Harrington says, "When I think across my 38 years as an amateur astronomer, one purchase comes to mind, and it was a gift. My parents gave me **7x50 Skyline binoculars** for my 15th birthday. They opened my eyes to binocular astronomy. With those binoculars, I was able to find 85 of the 109 Messier objects, qualifying me for the Astronomical League's Messier Club long before they instituted the Binocular Messier Award. I still use them every month, among others, to write my 'Binocular Universe' column" (see page 20).

HOMEMADE LIGHT-BLOCKERS shade light from fixtures near your observing location. (Approximately $40) DOUG KNIFFEN

Bargains also can help people other than the purchaser. Jackie Beucher, executive secretary of the Astronomical League, says, "I do a lot of public outreach and have helped many fledgling astronomers over the years. I bought a solid **mount** for my binoculars for about $80, and then a **Daisy Sight**, which, for less than $20, projects a red dot onto its view of the sky. Now I can show beginners an object on a star chart and point at the same place in the sky. Then they use the binoculars and Daisy Sight to aim in the right place. This gives them confidence to search on their own."

Like Harrington, Contributing Editor Glenn Chaple still has his astronomy bargain. "When I was in college in the late 1960s," he writes, "I purchased a **3-inch f/10 Edmund Scientific reflecting telescope** from a friend for $15. After graduation, I began using this scope in earnest, and my observations formed the basis for a *Deep Sky Monthly* column, which ultimately launched my career as an astronomy writer. I still use this scope — most recently to view Comet Schwassmann/Wachmann 3. It's quite possible that, were it not for that initial $15 investment, I wouldn't be writing for *Astronomy* today."

And so the stories go. I'll restrict my additions to this list to three: For safe storage and transport of eyepieces and accessories, Orion Telescope and Binoculars' aluminum **Pluck-Foam case** ($49.95) is a great deal. Rigel Systems' **StarLite** ($20.95), a dimmable red LED flashlight, has a permanent place in my observing kit. And, to avoid eye fatigue, nothing beats a $3.95 **eye patch** to cover your non-observing eye.

You can add a lot of enjoyment to your astronomy experience for less than $100. Keep your eyes and ears open for deals, and you never know what treasure you'll find.

Michael E. Bakich *is a senior editor of* Astronomy *who's made lots of observing friends through the years.*

Light pollution is a growing problem, but you can help curtail it.

/// BY BOB GENT

Simple steps to save the night sky

Backyard viewing of the Milky Way

is impossible in most major cities today. When my family moved to Phoenix in 1947, the city had fewer than 80,000 people and few streetlights. The night skies filled me with wonder. I badgered my parents and teachers with questions like, "How many stars are there? How far away are they?" Unfortunately, as the visible stars dim under today's growing sky glow, people don't often ask such questions.

The negative impacts of excessive nighttime lighting, not just for astronomy, are well documented. Spreading the word about what we can do to preserve our night skies is the mission of the International Dark-Sky Association (IDA). The IDA offers materials and resources to help amateur astronomers stay in the dark.

An organized effort

From its two co-founding members in 1988, the IDA has grown to some 11,000 members in more than 70 countries.

FULLY SHIELDED outdoor lights yield effective lighting while controlling glare. Check out the IDA web site, darksky.org, for a list of approved fixtures and other resources to fight light pollution. IDA

Besides a core of professional and amateur astronomers, IDA members include biologists, ecologists, doctors, urban planners, business owners, teachers, and students.

IDA's nearly 20-year-long goal to preserve the night sky for those who desire to observe it remains steadfast. But the mission now includes efforts to combat the effects of artificial night lighting on human health, surrounding nocturnal ecosystems, energy resources, and economic resources.

Legally binding

Growing public awareness of the negative effects of light pollution has inspired U.S. states, counties, and municipalities to pass more than 700 dark-sky-friendly ordinances. In 2000, New Mexico passed a Night Sky Protection Act. Other states have enacted laws, too; Florida has dozens of laws to protect sea turtles from light pollution.

Internationally, the number of communities passing laws to control outdoor lighting continues to climb. In 2002, the Czech Republic passed a national law to control light pollution. In 2000, the Lombardy, Italy, parliament passed a comprehensive law on outdoor lighting. Similar actions have been taken in Spain, Japan, and Australia.

Hundreds of communities have also established standards to control light pollution. The most effective outdoor-lighting ordinances have established brightness limits, required shielding in virtually all cases, and created lighting curfews.

To help communities create meaningful outdoor lighting legislation, the IDA and the Illuminating Engineering Society of North America (IESNA) together are developing a Model Lighting Ordinance (MLO), to be completed in 2007. The MLO will include a method to determine advisable limits on the total allowable lumens per

WHAT'S SO BAD?

There are many valid reasons for outdoor lighting at night, including visibility, security, safety, and an attractive nighttime environment. But not all lighting is good. Here are some components of bad lighting. — *B. G.*

GLARE
Harsh, bright light actually hinders visibility and is a problem for aging eyes.

LIGHT TRESPASS
This invading light shines into our yards and windows at night, disturbing the ambiance and our sleep.

POOR AESTHETICS
Overly bright lights create a harsh nighttime environment. Badly designed "prison yard" outdoor lighting can devalue residential properties.

ENERGY WASTE
In the United States, approximately $10 billion is wasted annually shining light when and where it's not needed and by using inefficient lights.

FALSE SECURITY
Bright lights may make us feel safer, but criminals may use light to their advantage, too.

ECO-*UN*SYSTEM
Many bird species that migrate at night are fatally attracted to lights shining from skyscrapers, broadcast towers, and other tall structures.

SKY GLOW
Poorly directed light and excessive lighting levels create sky glow, which destroys our view of the universe.

▶ LIGHT POLLUTION is a problem some 11,000 IDA members worldwide are battling. Some governments now restrict the types and amount of outdoor lighting at night. C. MAYHEW, R. SIMMON, M. IMHOFF (NASA/GSFC)/C. ELVIDGE (NOAA/NGDC)

◀ POCKETS OF DARK SKY remain in the western United States, but the network of lights in the rest of the country can be read as easily as a road map.

IDA/W. T. SULLIVAN, FROM DMSP DATA

TOO MUCH LIGHT is aimed into the sky needlessly in many places — like empty parking lots. Not only does this type of lighting miss its target, it wastes energy. IDA

square foot, and will address how, when, and where to impose lighting curfews.

Seal of approval

To encourage manufacturers to offer better lighting alternatives, the IDA initiated its Fixture Seal of Approval (FSA) in January 2005. This program helps differentiate a dark-sky-friendly lighting fixture from one that isn't. For a lighting fixture to gain FSA approval, it needs to be fully shielded, which means it emits no light above a horizontal line extending from the fixture's bottom.

Once a fixture is approved, the manufacturer can use the FSA logo on the light's packaging and promotional materials. More than 600 fixtures from more than 25 manufacturers currently are approved as dark-sky friendly. To see a complete list, visit the IDA web site at darksky.org.

Bob Gent *is a retired U.S. Air Force lieutenant colonel, past president of the Astronomical League, and vice-president of the IDA board of directors.*

For your health

Excessive night lighting can also adversely affect human health. At the 2006 IDA annual meeting, David E. Blask of Bassett Research Institute in Cooperstown, New York, spoke about his research and others' that suggest links between artificial night lighting's suppression of melatonin and increased growth of breast-cancer cells.

Melatonin is a natural hormone that helps regulate our day-night biological clock. In research trials, melatonin was shown to put breast-cancer cells to sleep, slowing their growth. Prolonged exposure to lights at night may reduce the production of melatonin and allow cancer cells to grow faster than they normally would. The National Institutes of Health is funding more research on this subject.

Take action now

We gain new and stronger evidence every year that the time for action is now. Not only are we destroying the night sky for observing, but we are adversely impacting wildlife, disrupting human day-night cycles, wasting energy, and hindering safety and visibility with excessive glare.

The IDA will continue to raise the alarm and endeavor to reverse the damage, but the days for widespread apathy are gone. The time is now to protect our observing sites — if we wait until bad lighting is installed, it is often too late. We must be proactive to save our night sky.

FIVE THINGS YOU CAN DO

Simple solutions exist to counteract many of the problems created by light pollution. The key is quality nighttime lighting. Here are some ideas for how to use artificial light at night properly. — *B. G.*

1. Shine outdoor lights downward, and only where they are needed.
2. Use time controls to ensure that lights are on only when they're needed. (You'll save money this way, too.)
3. Design and install lighting that minimizes glare. Most glare comes from poorly designed fixtures or poor installations.
4. Use the right amount of light for a task — don't overilluminate.
5. Use energy-efficient light sources. Visit darksky.org for suggestions.

ONLINE EXTRA Visit www.astronomy.com/toc to find out about the National Park Service's Night Sky Team.

ASK ASTRO

Astronomy's editors and experts from around the globe answer your questions about the cosmos. This month: Dark matter explained, how neutron stars generate magnetic fields, and what would happen if someone encountered a black hole.

DARK MATTER

Q: What *is* dark matter? — JACK KESSLER, EL CERRITO, CALIFORNIA

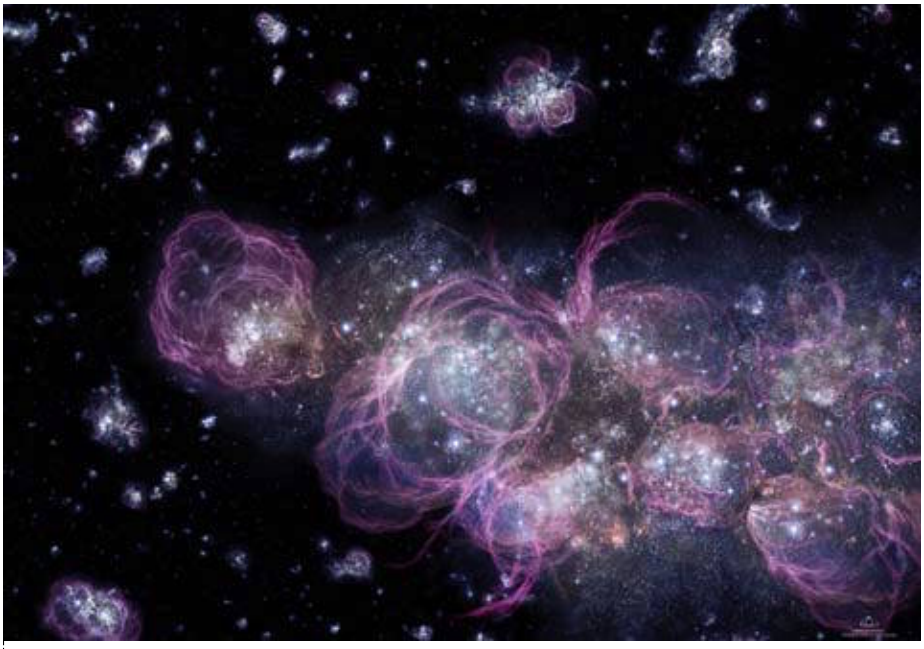
A: No one knows for sure. Dark matter was proposed by Swiss-American astronomer Fritz Zwicky (1898–1974) in 1933 to explain why the Coma galaxy cluster appeared to have a stronger gravitational field than expected if it were composed of matter that interacts with light.

The simplest model, constructed only to explain astronomical observations, asserted dark matter is a material that neither blocks nor emits light. Because adding a mysterious particle isn't the most elegant solution, scientists tried to imagine ways in which ordinary matter could hide from light.

For example, some scientists suggested dark matter might be ordinary matter — a dead star, or something else that, once cool, is hard to detect. Or, perhaps, it is bound inside black holes, from which no light can escape.

The objects would have left imprints on the cosmic microwave background, or on the proportions of elements produced in fusion reactions during the universe's first few minutes. Astronomers don't observe either of these imprints today. Also, such "baryonic dark matter" should form structures in our galaxy's halo we don't see today: Massive Compact Halo Objects (MACHOs). Groups have searched for MACHOs but have not found them.

Some theories predict dark-matter particles do interact with other kinds of ordinary matter, but only weakly. These Weakly Interacting Massive Particles (WIMPs) are the alternative to MACHOs.



THE FIRST STARS light up the infant universe in this illustration. Stars and galaxies now make up only about 4 percent of the cosmos' mass. Dark matter accounts for about 74 percent, while dark energy comprises some 22 percent of the universe. A. SCHALLER (STScI)

Experiments to detect such particles are being built. The Chicagoland Observatory for Underground Particle Physics is building a detector to look for an observable recoil from the collision of a dark-matter particle with an ordinary nucleus.

Meanwhile, when theorists construct new models of particle physics, they watch for any particle that behaves like dark matter. They look for something that interacts weakly, if at all, with ordinary forces such as electromagnetism (light), and the weak and strong nuclear forces, which are associated with nuclear reactions.

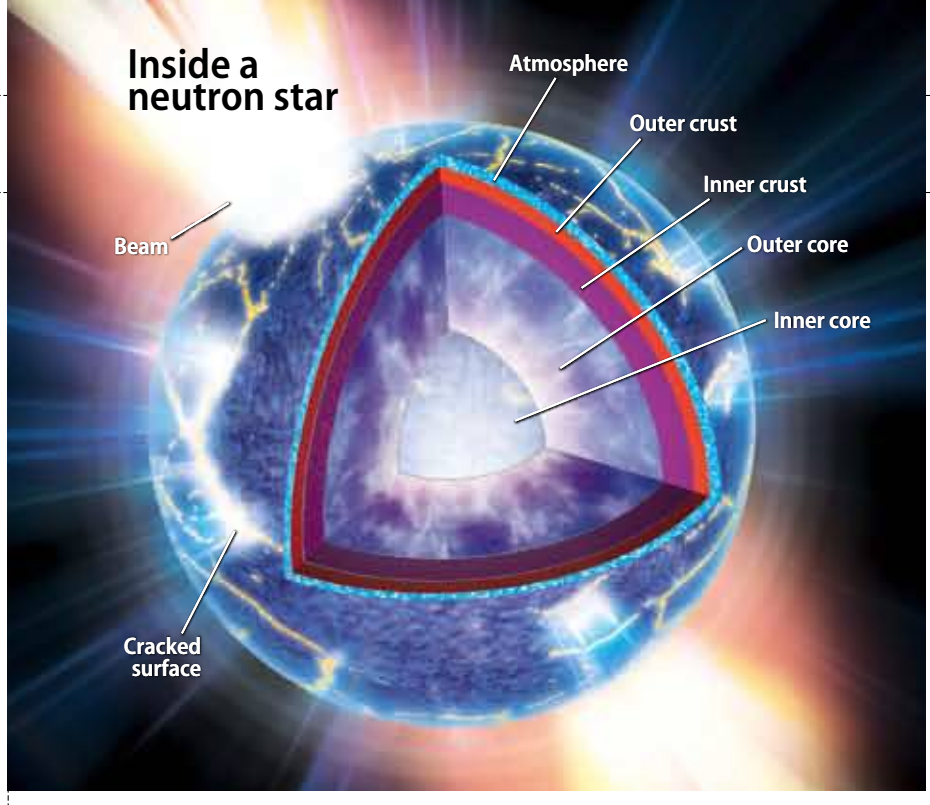
Dark matter, when it is found, will be recognizable as something stable that doesn't decay into ordinary matter, something heavy and slow-moving enough that it doesn't fly out of the clusters that started this debate, and something that light and the nuclear forces pass through almost unimpeded. — **SIMON DEDEO,** PRINCETON UNIVERSITY, PRINCETON, NEW JERSEY

MAGNETIC FIELDS

Q: How do neutron stars generate steady magnetic fields? — KELLY ARNOLD, JACKSON, MISSISSIPPI

A: A free neutron is an unstable particle that decays into an electron and proton in about 11 minutes. How can a neutron star exist if those neutrons are just going to pieces?

The Pauli exclusion principle says no two fermions — particles with half-integer spin values, like electrons — can occupy the same quantum state concurrently. All those tightly packed and gravitationally bound neutrons simply can't decay. The electrons released by their decay fill up all the available quantum states, something physicists call the Fermi sea. Once the Fermi sea fills up, no more neutrons can decay because no available quantum states remain.



ASTRONOMY: ROEN KELLY

A NEUTRON STAR'S INTERIOR is tightly packed with neutrons, along with plasma containing protons and free electrons. Free particles conduct electricity, which, in turn generates a magnetic field that is "frozen" into matter as the star collapses.

Thus, **bound neutrons coexist in a plasma along with a smaller concentration of free electrons and protons. These free particles conduct electricity, and electric currents generate magnetic fields.** While the details of what happens deep within a neutron star are a bit more complicated, the basic principles remain the same, and astronomers believe neutron-star matter is a good electrical conductor.

How does a neutron star's large-scale magnetic field form and evolve? Substantial evidence suggests neutron stars' large-scale surface field-strength can vary by almost 7 orders of magnitude. Field strengths in old, accreting neutron stars in binary systems probably reach about 100 million Gauss (Earth's magnetic field ranks around 0.5 Gauss). However, it's likely magnetars — stars with the strongest known magnetic fields — exhibit fields 10 million times stronger.

An interesting question is whether some neutron-star magnetic fields are relics of the progenitor star's field prior to the star's collapse. Because the collapse that forms a neutron star occurs rapidly, the magnetic field is "frozen" into the matter. This happens if the material is a reasonably good electrical conductor, a condition expected for most stars. When collapse occurs, and the core's surface area shrinks, the field strength goes up. In a spherical collapse, the field strengthens as the square of the star's change in radius. For a Sun-like star's collapse, the magnetic field strength may grow 5 billion times.

This probably isn't enough to account for strong magnetar fields. Just how these fields originate is still hotly debated. One possibility is that a dynamo process, somewhat similar to the process scientists think operates in the Sun, can generate magnetars' superstrong fields.

In the Sun, several known processes amplify magnetic fields. Differential rotation — a celestial body rotating faster at the equator than at its poles — can stretch and compress north-south field lines into east-west fields. The motion of turbulent plasma, coupled with rotation, converts the fields back and increases their overall strength. Although we still don't know how such a dynamo would work in a newborn neutron star, it seems likely the star must rotate rapidly to generate the strong field.

The rapid collapse that forms a neutron star probably leads to a differentially rotating body, but it's unclear if a dynamo forms. Maybe only the most rapidly spinning neutron-star progenitors have the ability to produce magnetar-strength fields. This might help explain why magnetars are so rare. — **TOD STROHMAYER,** NASA/GODDARD SPACE FLIGHT CENTER, GREENBELT, MARYLAND

IN THE KNOW

DARK MATTER
A material that neither blocks nor emits light.

MAGNETAR
A neutron star with an ultrastrong magnetic field. A neutron star forms when the core of a massive star collapses.

BLACK HOLE
An object whose gravitational field is so strong that nothing, not even light, can escape its powerful grasp.

BLACK-HOLE FALL

Q: What would happen if you fell into a black hole? — ZACHARY HANKS, SPANISH FORK, UTAH

A: Conditions near a black hole's event horizon depend on the black hole's mass. A person approaching a black hole would experience tidal forces — effects that arise due to objects not experiencing the gravitational force uniformly. Because gravity attracts parts closer to the hole more strongly, a traveler's head would feel a different pull than his feet.

Anyone venturing near a stellar-mass black hole would be torn apart by tidal forces. A person encountering a supermassive black hole (hundreds of thousands to tens of billions times the Sun's mass) could survive for many hours.

Eventually, however, as the person approaches the black hole's center, tidal forces become strong enough to tear the person apart. — **MARIO LIVIO,** SPACE TELESCOPE SCIENCE INSTITUTE, BALTIMORE

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

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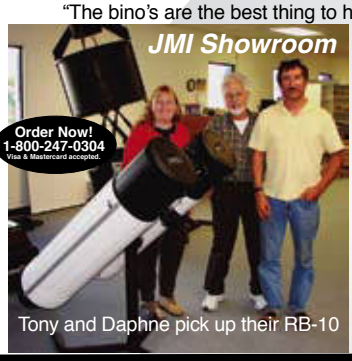

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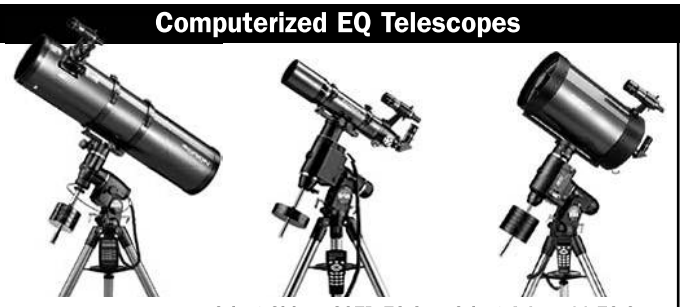

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IMAGINOVA

CCD cameras are revolutionizing astroimaging, enabling amateurs to capture more detail than ever before. /// BY ADAM BLOCK

Get the most from CCD images

CCD imagers have different challenges than visual observers. Even under light-polluted skies, a small telescope with virtually any digital-imaging device will reveal details not attainable in the visual realm. Take the Ring Nebula (M57), in Lyra, for example. It beckons imagers to reveal its secrets by exposing its light to a CCD camera for extended periods of time. Unfiltered images quickly reveal the central star, mottled gas, and the gossamer glow of IC 1296 — a magnitude 14.3 galaxy only 4' from M57's center.

Images taken through color filters show M57's multiple personae: a sphere of blue-green light, a large red wreath, and an eerie black center. The different colors indicate how strongly the gas is being ionized and made to glow.

These colors, unattainable with our eyes, are only the beginning of the story such an astronomical image tells. With good color balance and lack of brightness-clipping (brightness-clipping removes contrast from the image's brightest areas), the Ring Nebula's central star will be a brilliant sapphire that denotes its extreme temperature.

Not only will a high-quality CCD image allow you to see many stars other than M57's central star through the ring, but a trio of stars just to the north instantly characterizes the image's resolution. Two of these stellar points constitute a double star, and, if it is resolved, then the resolution of the image is better than 2".

Adam Block, *formerly of the National Optical Astronomy Observatory, is a world-renowned astrophotographer and author of* Making Every Pixel Count *(Caelum Observatory, 2006).*

Other bigger challenges await tenacious imagers. Just as visual observers strain their eyes' capabilities, imagers do the same with a telescope and CCD system. Long exposures of the Ring Nebula will reveal the concentric rings of mass-loss from an earlier time in the progenitor star's life. These ghostly shells transform the Ring Nebula into a rose of red and green that helps us imagine we are peering down the cylindrical axis of this bipolar outflow.

Non-linear brightness

The Santa Barbara Instrument Group ST-10XME CCD camera I used to photograph M57 is a 16-bit imager. This means it records up to 2^{16} (65,536) brightness levels. Neither computer monitors nor printed images, however, can display such fine brightness differences. Instead, images encompass a pixel-brightness range considerably smaller than the 16-bit version. Computer monitors are generally 8-bit displays, which show only 256 brightness levels, which are plenty for human vision.

The original pixel values for the M57 image at the top of page 79 range from the faintest (black) all the way up to nearly 65,536 counts, which represents white. Non-linear brightening processes modify the pixel values so both dim and bright pixels are more nearly equal. By compressing the dynamic range, the dimmest pixels in M57's outer envelope show up, while the brightest pixel values aren't overexposed.

The algorithm used on this data is called Digital Development (DDP), found in the image-processing software *Maxim DL*. For an input of small pixel values, the formula outputs a larger result. This brightens the dimmest image details. The user specifies a value beyond which pixel counts do not grow to brighter values. This turnover point from brightening to tempering pixel brightness is a powerful tool.

For the M57 image at the bottom of page 79, I employed aggressive compression of pixel values. I brightened values less than 3,000 counts significantly, and I output all greater values to a value not much larger. This creates an M57 image that is "flat" in terms of brightness but permits us to see the outer envelope and inner structures at the same time.

Imager's dream: the Horsehead Nebula

As December ends one year and January and February start another, Orion the Hunter climbs high in the sky. This allows amateur astronomers to visit one of the least accessible objects to observe visually but a most desirable target to image digitally — the Horsehead Nebula (B33).

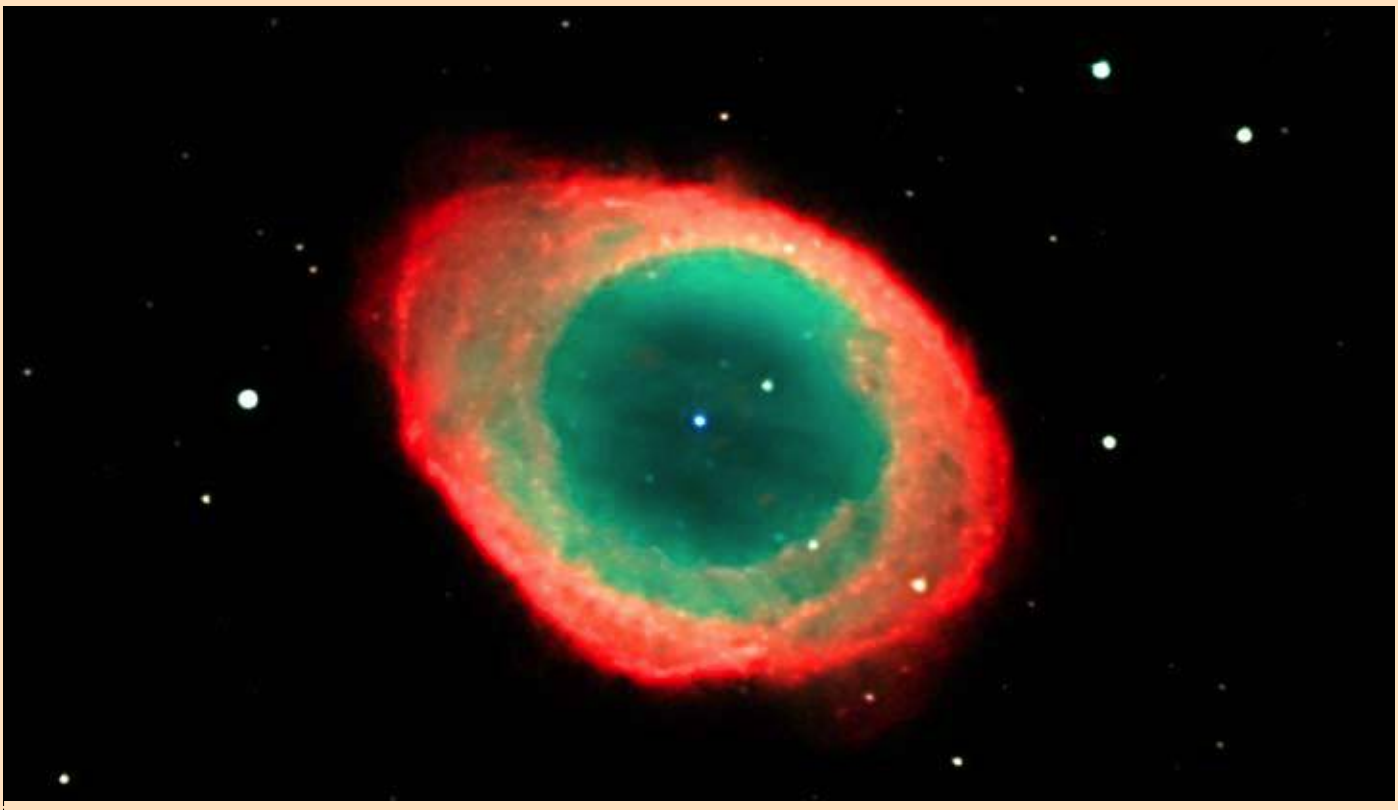
The Horsehead Nebula is a dense molecular cloud (a dark nebula) backlit by the red emission nebula IC 434. Sigma (σ) Orionis is the star near the top of the field of view and the one making IC 434 glow.

Colorful choices

To create a reproducible RGB (full-color) result of a multicolored region, such as the one surrounding the Horsehead Nebula,

ADAM BLOCK/NOAO/AURA/NSF

THE RING NEBULA (M57) offers imagers a target with multiple levels of detail. Short exposures reveal overall structure, the central star, and IC 1296, a magnitude 14.3 galaxy only 4' from M57's center. Longer exposures bring out color: blue, green, various shades of red, and the central star's sapphire hue. (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, Santa Barbara Instruments Group ST-10XME CCD camera, LRGB image with exposures of 85, 30, 30, and 30 minutes, respectively)



ADAM BLOCK/NOAO/AURA/NSF

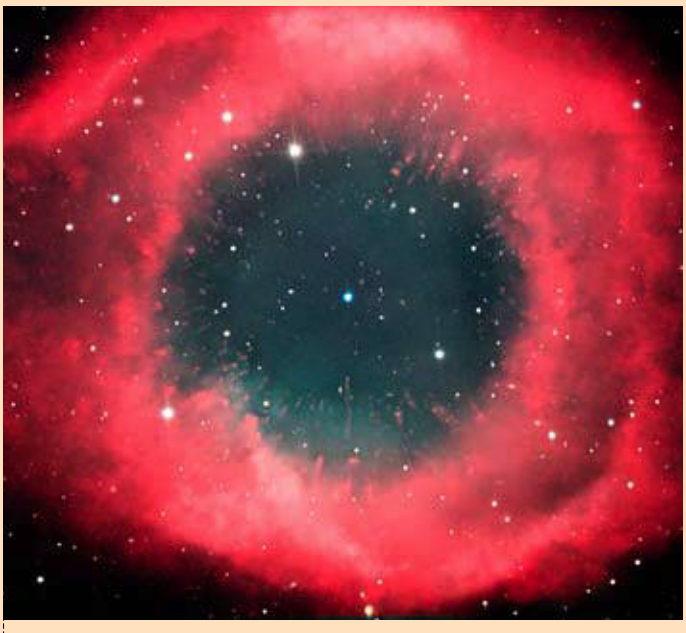
THE RING NEBULA (M57) in Lyra is easy to see through even small telescopes. The central star, now a white dwarf, blew off its outer layers several thousand years ago. To view the central star requires a large scope and high power. (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG ST-10XME CCD camera, LRGB image with exposures of 85, 30, 30, and 30 minutes, respectively)

PAT AND CHRIS LEE/ADAM BLOCK/NOAO/AURA/NSF

THROUGH A LARGE TELESCOPE, globular cluster M2 in the constellation Aquarius the Water-bearer explodes with detail. A CCD camera, however, reveals something you won't see through the eyepiece — the stars' colors. M2 shines at magnitude 6.6 and measures 16' across. (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG ST-10XME CCD camera, LRGB image with exposures of 25, 6, 6, and 6 minutes, respectively)

STEFAN SEIP/ADAM BLOCK/NOAO/AURA/NSF

BODE'S GALAXY (M81) appears as an oval haze through binoculars and small telescopes. Its structure, however, is difficult to resolve even through large scopes. With a CCD camera, however, dark lanes and wispy outer regions of the arms appear. (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/8.4, SBIG ST-10XME CCD camera, LRGB image with exposures of 120, 30, 30, and 30 minutes, respectively)



ADAM BLOCK/NOAO/AURA/NSF

THE HELIX NEBULA (NGC 7293) lies 450 light-years away in Aquarius. This object shines at magnitude 7.3 and measures nearly 18' across — more than half the diameter of the Full Moon. High-quality images reveal the central star, detail in the outer gas shell, and radial "fingers" of gas that penetrate the dark inner region. (20-inch RC Optical Systems Ritchey-Chrétien telescope at f/5.5, SBIG ST-10XME CCD camera, LRGB image with exposures of 135, 20, 20, and 20 minutes, respectively)

ADAM BLOCK/NOAO/AURA/NSF

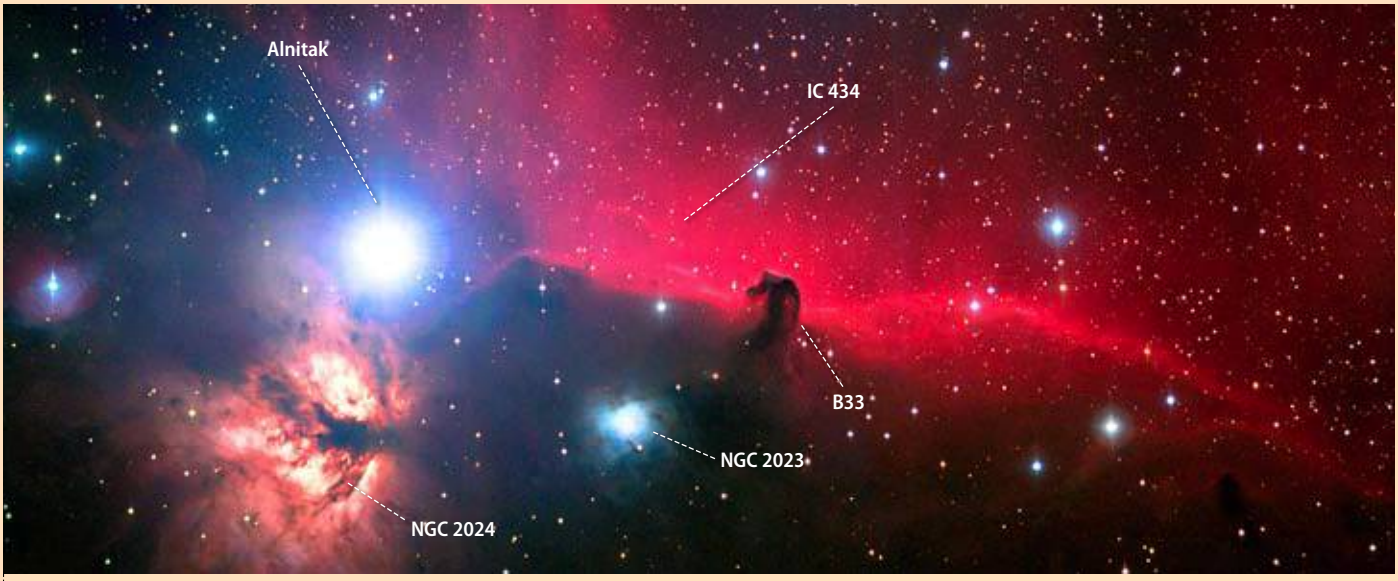
WHEN IN LEO, most observers concentrate on the bright galaxies M65 and M66. A bit more than 0.5° northeast of that pair lies NGC 3628. Through the telescope, the dust lane is visible as a dark streak, but with a CCD camera, you'll see detail in the dust clouds, feathering of the spiral arms, and several distant galaxies, which lie nearby. (16-inch RC Optical Systems Ritchey-Chrétien telescope at f/8, SBIG ST-10XME CCD camera, LRGB image with exposures of 120, 20, 20, and 20 minutes, respectively)

amateurs often use an object as a white reference to normalize the color responses of their optical systems.

One reason for doing this is CCD chips are generally more sensitive to red light than blue. Also, color filters have different transmission efficiencies, and even optics within a telescope may skew the color balance slightly.

The best example of what we call white is sunlight. Luckily, the night sky is filled with myriad Sun-like stars. Taking equal exposures through R, G, and B filters of a star of the same spectral type (G2V) as the Sun is called the solar-analog technique. The star, however, will not appear equally bright in each filtered exposure, as we would expect for our definition of white.

The relative brightness difference yields a set of coefficients whose ratios will give a white-balanced result. Once you obtain



LOUIS AND JENNIFER GOLDRING/REX WILCOX AND RAYNETT HULL/ADAM BLOCK/NOAO/AURA/NSF

THE REGION around the Horsehead Nebula (B33) offers astrophotographers lots of color. IC 434, which sits behind the Horsehead, is red; the Flame Nebula (NGC 2024), beneath the bright star Alnitak, is orange; and NGC 2023, beneath the Horsehead, is quite blue. (3-inch Tele Vue refractor at f/6.3, SBIG ST-10XME CCD camera, RGB image with exposures of 45, 45, and 45 minutes, respectively)

RYAN STEINBERG AND FAMILY/ADAM BLOCK/NOAO/AURA/NSF

THE HORSEHEAD NEBULA (B33) in Orion is one of the sky's most famous dark nebulae. The head measures about a light-year across and lies roughly 1,200 light-years away. It's tough to see visually, but easy to image. (16-inch and 20-inch RC Optical Systems Ritchey-Chrétien telescopes at f/8, SBIG ST-10XME CCD camera, LRGB image with exposures of 170, 20, 20, and 20 minutes, respectively)

these numbers, apply them to the color images by multiplying the exposure time by each. For example, if you choose 20-minute exposures, and your ratio turns out to be R=0.5, G=1, and B=2, your "balanced" exposures will be 10 minutes for red, 20 minutes for green, and 40 minutes for blue.

Other factors such as clouds, atmospheric extinction (for objects near the horizon), poor seeing, and light pollution may require small adjustments to your ratio. So, I didn't choose the colors in the close-up Horsehead image; instead, my white-balance determined them. For the system used to take this image of the Horsehead Nebula, the RGB ratio was 1 part red, 0.9 part green, and 1.55 parts blue.

The CCD camera has revolutionized amateur astronomy. With care, a discerning eye, and a bit of practice, you'll soon be producing your best images ever.

EQUIPMENT REVIEW

No telescope? No problem. Just pull out this handheld device, and you'll be identifying stars in no time. /// **BY GLENN CHAPLE**

Celestron's SkyScout

In January 2006, Celestron unveiled its SkyScout Personal Planetarium at the Consumer Electronics Show in Las Vegas. The instrument was a hit with judges, winning an innovation award. This portable, camcorder-sized device wowed show-goers with its ability to locate and identify thousands of night-sky objects. Will the SkyScout join the ranks of milestone advances in backyard astronomy, like the go-to drive and CCD camera? I was eager to find out.

Priced at $399, the SkyScout is a single-power, battery-operated sighting device with embedded Global Positioning System (GPS) and magnetic-field sensors. The instrument allows users to locate and identify more than 6,000 objects. Celestron programmed the Moon and planets, all 88 constellations, thousands of stars (including hundreds of double and variable stars), and more than 100 deep-sky objects into the SkyScout's database.

Graphic information appears on a 3" by 1" liquid-crystal display (LCD) backlit by an adjustable red light-emitting diode (LED). The device also has a stereo jack and earplugs to provide audio descriptions for more than 200 of the most popular objects. The audio mode also offers a built-in guide that contains a six-part astronomy lesson, a glossary of astronomical terms, biographies of celebrated astronomers, and more. The SkyScout is truly a planetarium at your fingertips.

Setup is simple: Press the power button and wait a minute as the SkyScout gets its GPS bearings. When you see the "Select" prompt on the display, you're ready for your night-sky adventure. To identify an object, center it in a pair of concentric circles in the viewfinder, then press the "Target" button. The object's identity, along with pertinent facts, appears on the display.

The "Locate" mode is just as easy. After choosing a target, peer into the viewfinder and move the SkyScout in the direction of the blinking red arrow. As you get closer, the arrow blinks faster. Run astray, and another arrow brings you back on course. A ring of flashing arrows announces when you have centered your target. As with "Target," the LCD provides informative facts about your selection.

Here in the northeastern United States, cold winter nights can wreak havoc on sensitive electronics. Because I tested the SkyScout in August, I simulated winter conditions by placing it (safely contained in an airtight bag) in the refrigerator for an hour before taking it outside. The chilled device worked without a hitch.

The SkyScout isn't just for nighttime use. On a sunlit morning in early September, I used it to locate Sirius, Rigel, and Betelgeuse. I even used it with a 6th-grade science class during an outdoor exercise to locate north. Sure, a simple compass would have sufficed, but the SkyScout mesmerized students as they watched it direct me to the North Star, Polaris.

The SkyScout even will pinpoint objects below the horizon. I programmed in the Moon on a day when it was Full. The circle of arrows began flashing when I aimed at the ground near my shadow — opposite the Sun, where the Full Moon should be.

Glenn Chaple *is a contributing editor of* Astronomy. *Read his "Observing basics" column on page 16.*

/// SPECIFICATIONS

CELESTRON'S SKYSCOUT

Dimensions: 2.5" by 4" by 7.4" (64mm by 102mm by 188mm)
Weight: 15.2 ounces (431 grams) without batteries
Display: Liquid crystal with LED backlighting; 3" by 1" (240x80 pixels)
Inputs and outputs: SD card slot, USB computer connection, 3.5mm stereo headphone jack
Power: Two 1.5-volt AA batteries
Database: 6,000 stars, 1,500 double and variable stars, all 88 constellations, more than 100 deep-sky objects, and more than 200 audio descriptions of popular objects
Price: $399

During the time I tested the SkyScout, the International Astronomical Union demoted Pluto from the ranks of planets. Could this and other discoveries in the fast-paced discipline of astronomy make the SkyScout obsolete? Not at all! The instrument has a USB port and cable that attaches to a Windows-based computer. Celestron's web site (www.celestron.com) announces SkyScout updates. One recent adjustment changed Pluto's status. Other updates already have corrected small errors in the SkyScout's database.

Is the device user-friendly? After only an hour of reading directions and trial-and-error practice, I was proficient with it. A non-astronomer friend I invited to try the instrument also was cruising the heavens within an hour.

The SkyScout was on the money when it came to locating and identifying bright stars and constellations, and it was flawless at picking up cosmic wanderers like the Moon and planets.

CELESTRON'S SKYSCOUT is a handheld, portable viewing device that turns the night sky into a personal planetarium. The SkyScout's point-and-click technology enables stargazers to identify more than 6,000 objects placed in the viewfinder or locate objects.

CELESTRON; STAR CHART: *ASTRONOMY*: RICHARD TALCOTT AND ROEN KELLY

Because the SkyScout's accuracy is limited to roughly 3°, it may not correctly identify stars in tightly packed constellations like Cassiopeia. On one night, the SkyScout had problems differentiating between Alpha, Gamma, and Delta Cas.

If you use the SkyScout a lot, like I did, invest in rechargeable batteries. It's powered by two AA batteries, and an icon in the display's lower-left corner indicates their status. "Full" to "Empty" happens after about 4 hours' use. Practice changing batteries in the daytime because I found the battery-compartment cover difficult to remove.

At times, a warning on the display said the device was receiving magnetic interference. This happens if a large metallic object or power line lies nearby. However, several warnings occurred in open areas. At first, I rebooted the SkyScout, but this takes time because it has to relocate the GPS satellites. Eventually, I discovered I could bypass the warning with no ill effects.

Celestron designed the SkyScout with the novice in mind, but would it have applications for an experienced amateur astronomer? Absolutely — especially if he or she is conducting a public star party. Just as the green laser has added a new dimension to star parties by allowing the presenter to point out sky objects to a large group, the SkyScout adds pizzazz to a gathering by providing useful information in an entertaining manner.

Despite my aversion to electronic gadgetry, Celestron's SkyScout won me over. It's fun to use (and especially fun to let others use) and accurate enough to help beginners find the planets, major stars, and constellations *for themselves*. And experienced skygazers aren't left out because the SkyScout makes a great teaching tool.

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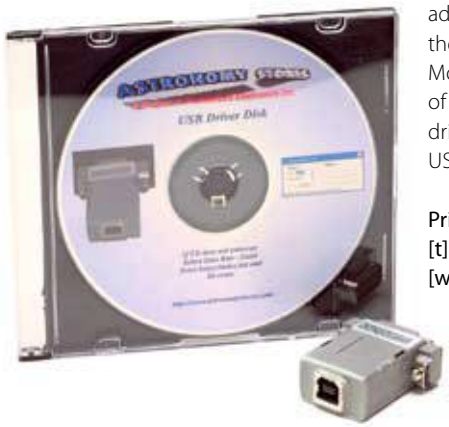

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The star-party season heats up after

winter. Although many early 2007 events are located in the southern United States, gatherings through the remainder of the year are found throughout the entire United States and Canada. Here are several events held in the spring or later:

THE GRAND CANYON'S Yavapai Point serves as the base for dozens of amateur astronomers who share their telescope views with visitors to this national park. *ASTRONOMY:* LIZ KRUESI

MAY 18–20
Texas Stars and Guitars
Lake Whitney State Park, Whitney, Texas. E-mail Thomas Williamson at distglow@sbcglobal.net.

JUNE 9–16
Grand Canyon Star Party
Yavapai Point, Grand Canyon National Park, Grand Canyon, Arizona. Visit www.tucsonastronomy.org/gcsp.html.

JUNE 14–17
Rocky Mountain Star Stare
Pike National Forest, near Lake George, Colorado. Visit www.rmss.org.

JUNE 15–16
Apollo Rendezvous
Boonshoft Museum of Discovery, Dayton, Ohio, and John Bryan State Park, Yellow Springs, Ohio. Visit www.mvas.org.

JUNE 15–17
North Dakota Star Party
Cross Ranch State Park, Center, North Dakota. Visit www.und.edu/org/nsas.

JULY 4–7
Green Bank Star Quest
National Radio Astronomy Observatory, Green Bank, West Virginia. Visit www.greenbankstarquest.org.

JULY 11–17
Shingletown Star Party
Shingletown Community Airport, Shingletown, California. Visit www.shingletownstarparty.org.

JULY 12–14
Table Mountain Star Party
Table Mountain, near Ellensburg, Washington. E-mail registration@tmspa.com or visit www.tmspa.com.

JULY 15–20
Nebraska Star Party
Merritt Reservoir, Valentine, Nebraska. E-mail info@nebraskastarparty.org or visit www.nebraskastarparty.org.

AUGUST 9–11
Weekend under the Stars
Near Foxpark, Wyoming. Visit home.bresnan.net/~curranm.

AUGUST 11–19
Mt. Kobau Star Party
Mt. Kobau, near Osoyoos, British Columbia. Visit www.mksp.ca.

AUGUST 16–19
Oregon Star Party
Ochoco National Forest, near Prineville, Oregon. E-mail ospqa@patch.com or visit www.oregonstarparty.org.

SEPTEMBER 6–9
Huronia Star Party
Camp Saulaine, Ivy, Ontario. Visit www.cois.on.ca/~ssaa.

SEPTEMBER 14–16
Black Forest Star Party
Cherry Springs State Park, near Coudersport, Pennsylvania. Visit www.bfsp.org.

SEPTEMBER 14–15
Cathedral Gorge Star Party and Campout
Cathedral Gorge State Park, near Panaca, Nevada. Visit www.lvastronomy.com.

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Okie-Tex Star Party
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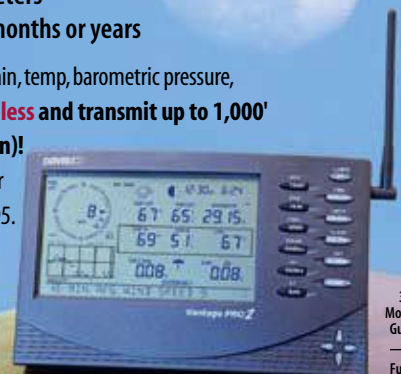
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Reader gallery

BABOQUIVARI PEAK (Nikon FE-2 film camera, 35mm f/1.4 Nikkor lens set at f/2, Fujichrome 1600 film, 60-second tripod-mounted exposure, taken March 24, 1991, at Baboquivari, Arizona) /// **ALLAN E. MORTON, REXBURG, IDAHO**

NORTHERN LIGHTS DISPLAY

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Auroral displays frequently shine in far-northern and far-southern skies. Occasionally, near times of solar maximum when the Sun is active, observers report aurorae from lower mid-latitudes. Such was the case March 24, 1991, when Allan E. Morton photographed the northern lights and many background stars silhouetting Baboquivari Peak (latitude 31.8°) in Arizona. Baboquivari Peak rises 7,734 feet (2,357 meters) above sea level.

According to the native Tohono O'odham people, Baboquivari marks the center of the universe and the home of its creator, I'itoli. Auroral displays occur when charged particles from the Sun, deflected by Earth's magnetic field, interact with Earth's upper atmosphere.

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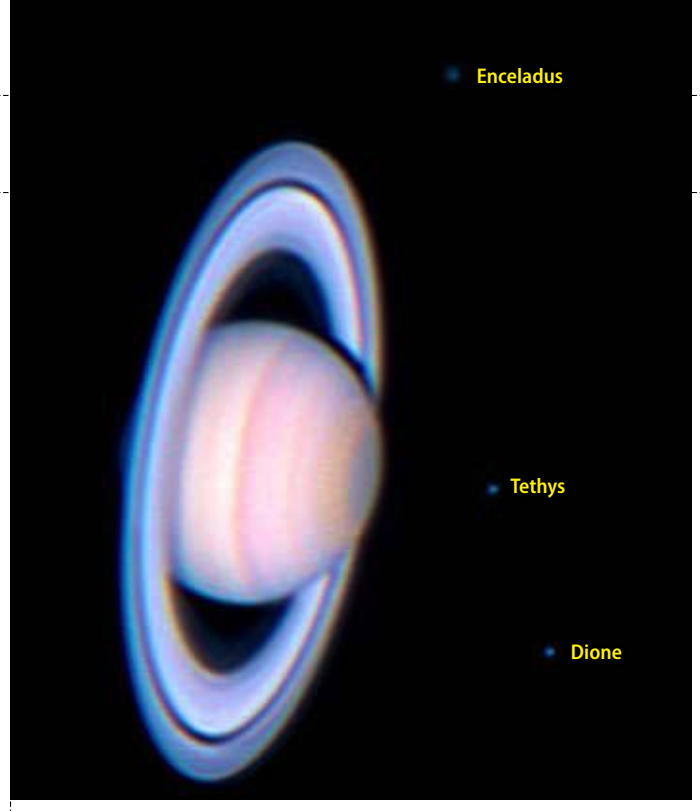
Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.

BARRED SPIRAL GALAXY NGC 1365 ranks as the Fornax galaxy cluster's second-brightest member. NGC 1365 shines at magnitude 9.3. (12-inch Meade LX200 Schmidt-Cassegrain telescope at f/4, Starlight Xpress MX716 CCD camera, LRGB image with exposures of 60, 10, 10, and 15 minutes, respectively) /// **MICHAEL SIDONIO, QUEANBEYAN, AUSTRALIA**

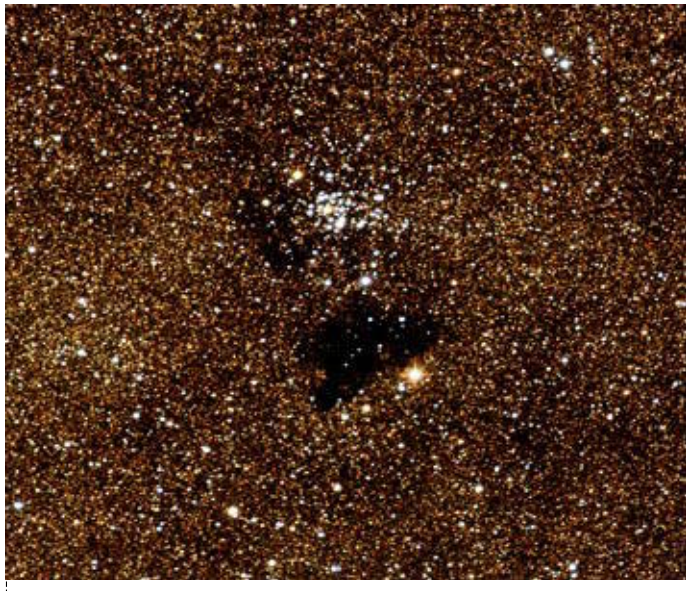
PECULIAR GALAXY Centaurus A (NGC 5128) is one of the sky's most recognized galaxies. The dust lane superimposed over its center forms a disk around this galaxy. Centaurus A shines at magnitude 7 and lies 15 million light-years away. (12.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/6.2, SBIG ST-2000XM CCD camera, LRGB image with exposures of 170, 50, 25, and 50 minutes, respectively) /// **R. JAY GABANY, SAN JOSE, CALIFORNIA**

EMISSION NEBULA Sharpless 2–129 glows faintly in the constellation Cepheus the King. Sometimes called the Flying Bat Nebula because of its shape, Sh 2–129 lies 2.5° south-southwest of Alderamin (Alpha [α] Cephei). (4-inch Borg apochromatic refractor at f/4, DTA C3 6303 CCD camera, HαRGB image with exposures of 120, 20, 20, and 20 minutes, respectively) /// **PAOLO CANDY, CIMINI ASTRONOMICAL OBSERVATORY, ITALY**

THE LAGOON NEBULA (M8) reveals diverse details through different filters. The top image is an LRGB visible-light image. Below it is a "quadrichrome" image, which combines a luminance exposure with three infrared-filtered exposures. The infrared filters' bandpasses ranged between 7,000 and 10,000 nanometers. (Both images: 8-inch TMB Super APO 203 at f/9, STL6303E CCD camera, Astrodon filters, 40-minute luminance exposure. Top image shot through Astrodon RGB color filters, 20 minutes each. Bottom image shot through Astrodon custom infrared filters, 20 minutes each.) /// **PAOLO CANDY, CIMINI ASTRONOMICAL OBSERVATORY, ITALY**



SATURN, as of this writing, has 56 known moons. This webcam image combines 844 individual exposures to reveal three of Saturn's largest satellites. (10-inch Orionoptics Newtonian reflector, Philips ToUcam Pro webcam, 844 exposures, each 1/25-second long, taken November 24, 2004, beginning at 2h31m UT) /// **RALF VANDEBERGH, WITTEM, THE NETHERLANDS**



DARK NEBULA Barnard 86 lies in Sagittarius the Archer and is easy to spot through binoculars as a dark triangular patch. Magnitude 7.6 open cluster NGC 6520 lies just above it. (18-inch Astroworks C-18 reflector at f/2.8, SBIG ST-2000XM CCD camera, LRGB image with exposures of 240, 50, 50, and 50 seconds, respectively) /// **DANIEL C. GOOD, MILLERSVILLE, PENNSYLVANIA**

THE OMEGA NEBULA (M17) in Sagittarius also is known as the Horseshoe Nebula. Best viewed through a nebula or deep-sky filter, this 6th-magnitude object spans 11'. M17 lies approximately 5,000 light-years away. (6-inch Takahashi FCT-150 apochromatic refractor at f/5, Canon modified 300D digital SLR, fifteen 5-minute exposures at ISO 800) /// **MARK HANSON, MADISON, WISCONSIN**

THE COATHANGER is an asterism also known as Collinder 399. You can see this 1°-long grouping of about 40 stars easily through binoculars. It lies in the northern constellation Vulpecula the Fox. (7.2-inch Takahashi Epsilon 180ED hyperbolic astrograph at f/2.8, SBIG STL-11000M CCD camera, RGB image with ten 3-minute exposures through each filter) /// **RICHARD BEST, SUSSEX, ENGLAND**

Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Canada Publication Mail Agreement # 40010760.

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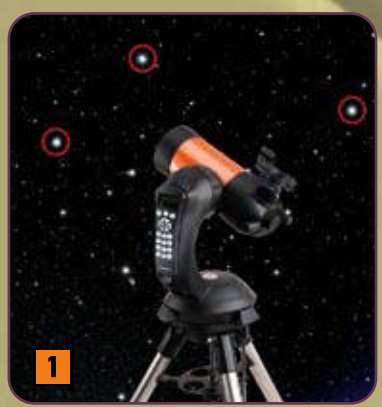

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